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Cold Roll Forming

By E. J. VANDERPLOEG. (From *Iron and Steel Engineer*, U.S.A., Vol. 32, No. 10, October 1955, pp. 76-81, 7 illustrations.)

ALTHOUGH cold roll forming is by no means a new process, its use did not become widespread until the demand for automobiles became so great that better and more rapid methods of producing sheet-metal parts were required. Primarily intended for large volume production, cold roll forming is a process of forming metal from sheet, strips, or coiled stock into shapes of uniform cross-section, by feeding the stock longitudinally through successive pairs of rolls, each pair of rolls progressively forming the stock until the finished cross-section is produced. The parts so produced are uniform in cross-section and dimensionally held within very close tolerances. These tolerances depend, of course, somewhat on the gauge tolerances on the material being formed, but may be as close as ± 0·002 in. on small shapes formed from light-gauge material. Because cold roll forming has satisfied the need for equipment to produce economically and quickly uniformly accurate parts, its use has spread until, to-day, it is being used wherever metal is processed into shapes of uniform cross-section.

Cold roll-forming machinery is built in a range of sizes to form material from several thousandths of an inch up to 0·5 in. thick. This material varies in hardness from dead soft up to the high-strength steels used for structural purposes. To form this range of material, machines have been designed with roll-spindle diameters from 1 to 15 in., and with roll passes numbering from two up to thirty or more.

The most popular type of roll-forming machine at present in use is built with roll spindles ranging from 1¼ in. to 3½ in. in diameter. The length of the roll spindles or the width capacities of this type of machine can be varied to suit any practical width of material by providing larger spindles and a wider baseplate. Its unit construction permits flexibility in the number of spindles or roll passes. The machines can be provided with a small number of spindle units, but with a baseplate capacity for a much greater number, thus providing for future needs. The drive is direct from a high-torque motor or variable-speed unit through "V" belts or a chain to the worm shafts of the units. The worm shafts of the individual units are coupled through chain-type couplings. The bottom spindle is directly driven from a worm gear. The top spindle is driven through a toggle gearing arrangement which permits considerable vertical adjustment of the top spindle, without disengaging the gears from their proper mesh. The roll diameter can then change to accommodate various depths of shapes and, when rolls are properly designed, they can be re-dressed many times to smaller diameters, extending their useful life indefinitely. For convenience in mounting rolls and making adjustments, the machines are equipped with micrometer dials on the top-spindle adjustment.

Although manufacturers of roll-forming equipment vary their designs in detail, it is general practice to build such machines with variable vertical centre distance on the spindles, unit construction of the driving heads, and a base design which can easily be adapted to variations in the number and length of spindles.

Because automation to-day is becoming more and more necessary to produce parts more economically and more accurately, roll-forming equipment is being combined with other equipment, for the complete manufacture of parts with a minimum of handling. Most important and most commonly used is some type of flying cut-off machine to cut off the shape after it is formed in the roll-forming machines. This is necessary because material for roll forming is furnished mostly in coils and the product is generally a straight piece from several inches to many feet in length.

In one type of cut-off machine, the formed shape passes through the open die until the end of the piece strikes a target which trips the press. As the cut is being made, the die is carried along the die table on slides by the shape until the cut is completed. Then, springs return the die to its original position, ready for another cycle. The target is adjustably mounted along a run-out table to vary the length of the finished pieces. This type of cut-off machine maintains uniform lengths of cut to a very close tolerance (± $\frac{1}{64}$ in.). Another type, designed for cutting shapes which lack column strength for pushing the die while the cut is being made, is equipped with a power-driven die table. Still another type uses a saw instead of a die for cutting shapes which are liable to collapse if cut with a die. These flying-shear types of cut-off machines are frequently installed at both the entrance and exit ends of the roll-forming machine. The first cut-off then prenotches the flat strip, partially to make the cut. After passing through the roll-forming machine, a second machine, indexing from the notch, completes the cut, to produce a shape of cut end not possible with one die.

Rings, such as bicycle rims, headlamp rims, and curved parts, can be formed and coiled in the roll-forming machines and cut off into individual rings in special flying-shear cut-off machines. Polishing units, printing and embossing rolls, piercing rolls, and slitting rolls are combined with roll forming in unique applications. Combined with various types of gas and electric welding equipment, welded tubing and pipe are being produced by cold roll forming at speeds up to 200 fpm, and in sizes from ¼ in. up to 26 in. in diameter.

To increase further the production and efficiency of cold roll-forming equipment, supplementary equipment is often used. Where maximum production is of extreme importance, butt welders combined with looping arrangements are employed. By unwinding into a loop, the trailing end of a coil of material already partially formed and being passed through the forming machine is butt-welded to the starting end of a new coil of material without stopping production, thus making possible a continuous flow through the machines.

Where volume production warrants it, slitting equipment is of economical importance in supplying the proper width of stock to the machines. It enables the manufacturer of roll-formed products to order and carry in stock only wide coils of material, slitting it to the proper width when needed.

The rolls for forming shapes are generally supplied by the manufacturer of the machines, but can be made in any well-equipped tool room by anyone experienced

in the design and manufacture of rolls. There are several methods of designing and making rolls, the choice of methods used depending on the knowledge, skill, and machinery available. The most important and also the most difficult part in all methods is the planning of the progressive shaping of the material which determines the number of roll passes necessary to form a shape. This requires experience, good judgment, and some knowledge of the bending of metals. The forming progresses from the middle of the sheet outwards to the edges, and generally the edges are formed upwards. Once the plan for producing the shape and the number of roll passes has been established, the rolls are designed and made either from roll drawings which have been very carefully and completely dimensioned, or from templates. If drawings are used in preference to templates, they must be prepared by a draughtsman, skilled in the use of trigonometry to the extent that each change in contour on the roll must be dimensioned both for diameter and length. The rolls are then manufactured from these drawings without the use of templates.

If templates are used, they are prepared either from multiple-size layouts and reduced on a pantograph type of machine, or made to exact size directly by a skilled template maker. In machining the rolls it is obvious that, because of the number of steps involved in the design and manufacture, accuracy must be held in each of the steps, in order that accumulated errors will not result in an unsatisfactory product.

Rolls are made from a number of different materials, depending on their use, taking into consideration the fact that a large part of the cost of these forming rolls is in the design, manufacture, and development of the rolls to produce a satisfactory product. Thus, the difference in cost of the roll material does not represent the actual difference in cost of the rolls made from them. Although not commonly considered for roll material, treated wood and resin-impregnated materials have been used for rolls for forming simple shapes of light-gauge material for short production runs. The advantage gained in using these materials is mainly in the time saved in getting into production. Wood rolls are known to have produced as much as a quarter of a million feet without replacement. Most commonly used is a medium-priced oil-hardening tool steel, hardened to 60-63 Rockwell C. When roll forming unpickled hot-rolled steel, a high-carbon, high-chromium roll material is used because of its resistance to abrasion.

Cast iron and soft machine steel are used for spacer rolls and for forming light-gauge shapes. Contours and bores of rolls are generally ground after hardening to ensure concentricity. The pairs of rolls are always checked and matched for proper clearances before mounting in the machine.

The ground finish is generally suitable for forming hot- or cold-rolled steel sheets, but highly polished rolls are necessary for forming stainless steel and enamelled or coated stock. Chromium-plated rolls are often furnished for forming highly polished or coated material. Rolls are generally made in sections for convenience in machining, handling when mounting on the machine, and replacing of worn sections.

The life of a set of rolls depends on the type of material being formed, the gauge and shape being formed, and the care which is given them. Rarely is a complete set of rolls replaced because of wear. If parts of rolls subject to wear are replaced when worn, and before extra work is placed on succeeding roll passes, the set of rolls will last indefinitely.

With machines designed to accommodate varying roll diameters, the complete sets of rolls can be re-dressed a number of times, reducing the diameters each time, but maintaining the contours of the rolls to produce a shape within the required tolerance. Rolls have produced up to five million feet without re-dressing, and up to fifty million feet or more when properly re-dressed and maintained. Modern roll-forming machines are all provided with roll-lubricating systems which add greatly to the life of the rolls and help to produce a better product.

The materials from which roll-formed products are made include practically any metal ductile enough to form without appreciable thinning of the gauge of the stock. It is furnished generally in coils, in which case it is fed into the forming equipment from coil boxes or reels, and is cut off, after forming, with an automatic cut-off machine. Some materials, such as thin-gauge wide sheets, are often furnished cut to length and fed from roller-type tables into the forming line. Intricately shaped and pierced blanks are also readily formed by this process, although care must be exercised in this case to prevent distortion of pierced parts.

About 98% of all material used for roll-formed products is slit-edge material, the rest being mill-edge stock. Mill-edge material is difficult to obtain in the various gauges and widths demanded by the cold roll-forming industry. The width tolerances are not always close enough to suit the tolerances on the product. One possible objection to using slit-edge stock is the burr or raw edge on the finished product. Although it is not practical to round the edges in the roll-forming process completely, it is possible to condition them sufficiently to eliminate hazards in handling the finished product. To-day, most of the large manufacturers of roll-formed products have their own slitting equipment.

Practically all types of finished surfaces are readily roll-formed without injury to the surface. Hot-rolled unpickled steel is often formed with only a decreased roll life and a cleaning problem on the equipment as necessary considerations. The very highly finished stainless steel requires only polished rolls, careful lubrication, and care in handling. Galvanized, plated, or treated surfaces are not injured in the process. Pebbled and embossed materials are successfully formed, as are the new prepainted and plastic-coated materials.

Although generally considered a process strictly for forming or bending metal without changing the thickness or removing material, it is possible to carry out coining, embossing, piercing, and slitting. Sharp edges of slit material can be rolled to make rounded edges. On ornamental shapes where the corners on the outside of a bend are required to be sharp, the corners can be coined to appear sharp. Intricate designs can be embossed or impressed into the metal with engraved rolls. Piercing of a continuous row of holes can be accomplished with special piercing rolls.

Looking into the future of this industry, signs of an expanding field can already be seen. Thus, for example, metal is being used in increasing amounts for the outside of buildings. Also, it is conceivable that, sometime in the future, roll-forming machines may be made portable, making it possible to roll-form shapes to extend the entire length or height of a building, thus eliminating any cross-joints.

Another field only slightly explored is the roll-forming of structural shapes from plate, instead of the hot roll shapes being used at present. Shapes thus formed are exceptionally well adapted for use in welded construction, as the rounded corners at the bends and the square edges present good conditions for welded joints. Small structural shapes, such as the very popular $1 \times 1 \times \frac{1}{4}$-in. angle, can be more economically made from flat strips than by hot rolling, as various gauges of material and edge dimensions can be produced on the same set of rolls. On these light-wall shapes, enough coining can be done in the roll-forming process to produce round corners at the edges, and also sharper corners at the outside of the bends.

When product engineers become aware of the possibilities of cold roll forming, this industry can absorb a large percentage of the increased outputs of steel mills.

Measurement of the Temperature of a Fluid in Motion

By R. ÉCABERT. (From *Bulletin Technique de la Suisse Romande*, Vol. 81, No. 21-22, October 20, 1955, pp. 406-411, 6 illustrations.)

THE determination of the temperature of a fluid in motion requires certain precautions. The thermometer exchanges heat with the fluid by conduction (and also, in some cases, by radiation); in addition, it exchanges heat with the walls by radiation and conduction. The measured temperature is the result of these various exchanges of heat. The accuracy of the temperature indication will be increased by reducing as much as possible the heat exchange with the walls, while ensuring that favourable conditions are obtained for heat exchange with the fluid [1,2,3].

To reduce the error due to radiation at high temperatures, it is first necessary to decrease the difference in temperature between the fluid and the walls. This can be achieved by careful thermal insulation of the wall outer surfaces, or even by external heating of the walls. In addition, the thermometer can be surrounded by one or more reflecting shields, which assume temperatures between the thermometer temperature T_m and the wall temperature T_w. An arrangement of this type was employed by King[1]. The hot junction of a thermocouple is located at the end of a central tube, and the fluid flows freely between four screens arranged around the thermocouple.

In the following, it will be assumed that the temperatures to be measured do not differ appreciably from ambient temperature, and that heat exchange between thermometer and walls can be neglected.

INFLUENCE OF FLOW VELOCITY

In the temperature measurements of a fluid in motion, it is necessary to make a distinction between "static" and "stagnation" temperatures. The "static" or true temperature T_s [°K] is that which would be measured by a thermometer moving with the fluid. The "stagnation" temperature T_a [°K] is that which the fluid would assume if it were compressed (dynamically) to zero flow velocity, without exchange of heat or work with the surroundings. Their difference is termed the "dynamic" temperature ΔT_d and is defined as

$$\Delta T_d = T_a - T_s = c^2/(2c_p)$$

where c = flow velocity of the liquid [m/sec], and c_p = specific heat of the fluid at constant pressure [kilojoules/kg°C]*. In the case of air, with $c_p \cong$ 1000 kj/kg°C, $\Delta T_d = 5°$ C for $c = 100$ m/sec, and 45° C for $c = 300$ m/sec.

The insertion of a thermometer disturbs the flow pattern of the fluid. A stagnation point is formed, with decreased flow velocities, ahead of the thermometer. Moreover, there is friction of the fluid on the thermometer walls. Both effects increase the temperature of the thermometer to a value higher than that of the static temperature of the fluid in motion. Generally, the measured temperature T_m is a value between T_s and T_a. However, with high Prandtl numbers (Pr = ν/α, where ν = kinematic viscosity [m²/sec] and α = thermal diffusivity [m²/sec] of the fluid), for instance, for water at 20° C and Pr = 7, it may even exceed the stagnation temperature.

The temperature of a gas of known composition in motion can be determined indirectly, without disturbing the flow, by means of pressure measurement and optical or electrical determination of density[4]. This method, however, lacks precision and requires complicated equipment, so that a simple thermometer is mostly used.

*The Giorgi system of units is used in this article. Accordingly, specific heat has the dimensions

$$\frac{\text{kilojoules}}{\text{kg °C}} = \frac{\text{kg m}^2\,\text{sec}^{-2}}{\text{kg °C}} = \frac{\text{m}^2}{\text{°C sec}^2}$$

THE HEATING COEFFICIENT

The "heating coefficient" (recovery factor) r of a thermometer is defined as

$$r = (T_m - T_s)/\Delta T_d.$$

The value of r depends on the type of thermometer used, its dimensions, position, and orientation relative to the direction of flow of the fluid, as well as the Mach number, the Reynolds number (degree of turbulence of the flow), and the Prandtl number of the fluid. It is essential to know the correct value of r for accurate temperature measurement of a fluid in motion, but the determination of this heating coefficient is difficult.

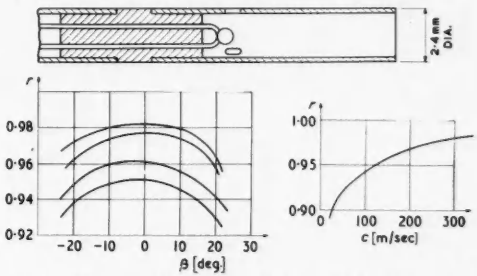

Fig. 1. **Thermometer used by Hottel and Kalitinsky, with its calibration curves.**
Left: Heating cofficient r as a function of angle of yaw β between direction of flow and thermometer axis, for c = 300, 270, 175, and 130 m/sec.
Right: Heating coefficient r as a function of flow velocity c, for $\beta = 0$.

A theoretical calculation of r was made by Pohlhausen[5] in 1921 for the case of a plate type of thermometer in an incompressible fluid, taking account of the boundary layer in laminar flow. He found that $r = \sqrt{\text{Pr}}$, for Prandtl numbers less than 10, which is in good agreement with measurements by Eckert[6]. The calculation was extended to the cases of laminar compressible flow and turbulent incompressible flow by other investigators[7,8,9,10]. However, for thermometers of all other types, the heating coefficient has so far only been determined experimentally.

The first attempts at measuring temperature in fluids flowing at supersonic velocities were made by Stodola[11], Batho[12], and Nusselt[13], and gave dissimilar results, with indicated values exceeding by more than 100° C in some cases the calculated static-temperature values. Müller[14] repeated these tests in 1920 and found that, by using moist vapour in one test and dry vapour in another, it was possible to obtain systematically the variations previously reported, the water deposited on the thermometer in the first test being therefore the modifying factor.

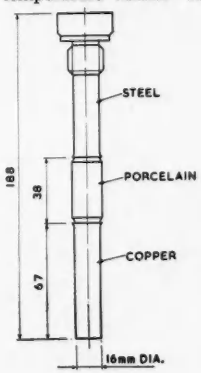

Fig. 2. **Protective pocket for mercury thermometer.**

Many measurements have been made by various investigators for determining the heating coefficient of thermometers, the values obtained being between 0·65

and 0·90 for thermocouples[6,15,16] (depending on type, diameter of leads, etc.) and between 0·59 and 0·63 for ordinary mercury thermometers in a protective pocket[17,18]. Endeavours were also made to develop special thermometers[1,2,6,15,16,18,19] for fluids in motion. An example of one such thermometer, tried out by Hottel and Kalitinsky[16], is shown in Fig. 1, together with its corresponding curves. The thermocouple junction is situated at a position where flow velocity is low, lateral holes permitting the necessary flow of air.

Test Installation and Evaluation Procedure

It was considered of interest to measure the heating coefficient r of a standard type of mercury thermometer inserted in a protective pocket, for air-flow velocities between 50 and 100 m/sec.

The type of protective pocket used is shown in Fig. 2 and the test installation is illustrated in Fig. 3. The cooling unit was used in order to cool down to ambient temperature the air issuing from the blower. Let T_{m_0} = temperature at inlet, T_{m_1} = temperature in measuring section, p_{a_0} = stagnation pressure at inlet, Δp_{d_1} = dynamic pressure in measuring section = $p_{a_1} - p_{s_1}$, where p_{s_1} = static pressure.

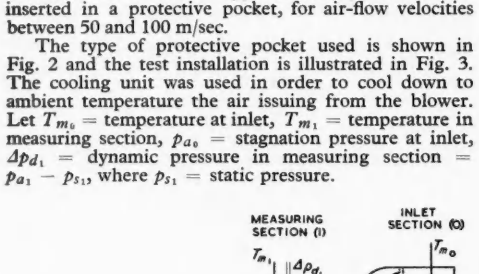

Fig. 3. Schematic layout of test installation.

The air is accelerated from section (0) to section (1) (Fig. 3) in a nozzle of suitable aerodynamic shape, and it may be assumed that the compression is isentropic ahead of the Prandtl tube used for determining Δp_{d_1}. Consequently,

$$T_{a_0} = T_{a_1} = T_a.$$

From the definition of r, it follows that

$$T_a = T_{m_0} + (1 - r_0)\Delta T_{d_0} = T_{m_1} + (1 - r_1)\Delta T_{d_1}$$

where $T_d = T_a - T_s$ = dynamic pressure at the corresponding positions (0) and (1). The flow velocity at the inlet is so low that it can be assumed that $\Delta T_{d_0} = 0$, or $T_{m_0} = T_a$. (It can be shown that the relative error thus introduced is about 0·25%, so that this simplification is acceptable.) Furthermore, with $\gamma = p_c/c_v$, and $(\gamma - 1)/\gamma = n$,

$$\Delta T_{d_1}/T_a = (T_a - T_{s_1})/T_a = 1 - (p_{s_1}/p_a)^n$$
$$= 1 - [1 - (\Delta p_{d_1}/p_a)]^n$$
$$\cong 1 - \left[1 - n\frac{\Delta p_{d_1}}{p_a} - \frac{n}{2\gamma}\left(\frac{\Delta p_{d_1}}{p_a}\right)^2 + \cdots\right]$$

so that $\Delta T_{d_1}/T_a = n\,(\Delta p_{d_1}/p_a)\,\{1 + \Delta p_{d_1}/(p_a 2\gamma)\}$

and, as $T_a - T_{m_1} = \Delta T_m = (1 - r_1)\,\Delta T_{d_1}$,

$$r_1 = 1 - \frac{\Delta T_m}{T_a}\,\frac{\gamma}{\gamma - 1}\,\frac{p_a}{\Delta p_{d_1}}\left[1 - \frac{1}{2\gamma}\,\frac{\Delta p_{d_1}}{p_a}\right]$$

This equation enables r_1 to be calculated from measured values (γ being a known function of T_s). p_a was equal to the atmospheric pressure; Δp_{d_1} was measured with a Prandtl tube, located immediately ahead of the test thermometer. During the tests, this Prandtl tube was drawn up close to the duct wall, to avoid disturbing the flow around the thermometer. After the measurement of T_{m_1}, the Prandtl tube was placed in position for determining Δp_{d_1}, which was measured with an error definitely less than $\pm 2\%$.

As the temperature distribution at the inlet section was not uniform, it was decided to measure the temperature at the inlet by means of seven carefully calibrated thermometers distributed over this section. The mean T_{m_0} value obtained was used for the subsequent evaluations.

The protective pocket of the test thermometer (Fig. 2) was designed with a copper end-piece and a middle section of porcelain, which reduced heat exchange through conduction between the thermometer and the walls. The thermometer was immersed in oil (the oil level not quite reaching up to the porcelain) and lagged with asbestos around the porcelain section to avoid heat exchange through convection. The blower was operated for at least one hour before taking the first measurement and then run for another half-hour before the second measurement. Good agreement between these two measurements indicated that steady-state conditions were reached.

The magnitude of the effect on the thermometer reading due to the exchange of heat between thermometer and walls was assessed theoretically, taking account of the heat-transmission coefficient of the copper portion of the protective pocket (diameter d = 0·016 m), the coefficient of heat transfer U of the air, and Péclet's number (Pe = cd/α), so as to obtain the heat exchange due to radiation and conduction. It was found that the effect did not exceed 2% of $(1 - r_1)$ and therefore could safely be neglected.

Results of Tests

The measured values were evaluated by statistical methods. It was found that, in the range of velocities considered, the heating coefficient can be regarded as independent of the flow velocity. In this manner, a weighted mean was obtained for the heating coefficient r of a mercury thermometer, i.e., r = 0·60 (within the limits +0·04 and −0·03).

The tests were made with Mach numbers varying from 0·12 to 0·30 and Reynolds numbers from 40,000 to 100,000 (referred to the diameter of the protective pocket). These Reynolds numbers indicate that the boundary layer around the protective pocket was still in a laminar condition. The possibility of carrying out further tests with higher degrees of turbulence, i.e., at higher Reynolds numbers, obtainable by fitting wire gauze at the duct inlet, is now being considered.

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Explosive-Action Circuit-Breakers

By E. MARX. (From *Elektrotechnische Zeitschrift* (*ETZ*), Vol. 76, No. 21, November 1, 1955, pp. 765-769, 5 illustrations.)

EXTREMELY rapid breaking of circuits can be important when the dynamic or thermal effects of short-circuit currents become difficult to control; otherwise, severe damage to valuable equipment, as well as disturbances in large networks, may occur.

Direct-current quick-acting switchgear is particularly employed in high-power d.c. installations fed from three-phase networks. Short-circuit currents can reach much higher values in d.c. networks than in a.c. networks, because in d.c. circuits only the ohmic resistances are effective. Moreover, in large d.c. plants many generators are often connected in parallel, so that the ratio of the short-circuit current of the entire plant to the nominal current in each unit can assume extremely high values.

Suitably designed quick-acting switchgear is thus required to operate both in the case of excessive increases in current above the nominal value and in the case of reverse currents. Switches with an explosive release action will in all cases prevent the short-circuit current from reaching its peak value, as the steepness of the current rise is limited by the self-inductance of the short-circuit. For instance, if a short-circuit current is limited to one-third of the maximum value otherwise occurring, only one-ninth of the dynamic effect and a very small fraction of the thermal effect will be produced, resulting only in a slight burning of the contact members of the quick-acting circuit-breakers.

Explosive-action switches of the types described in the following are also suitable, in principle, for single-phase and three-phase alternating currents and serve to switch out alternating currents, irrespective of the current passing through zero value, avoiding dangerous overvoltages.

MECHANICAL FEATURES OF EXPLOSIVE-ACTION CIRCUIT-BREAKERS

Tests using explosive charges for circuit-breaking purposes were undertaken some years ago, but the first successful results were achieved by the arrangements described in the following. These enable the time required for breaking to be reduced to 10% of the best values previously obtained.

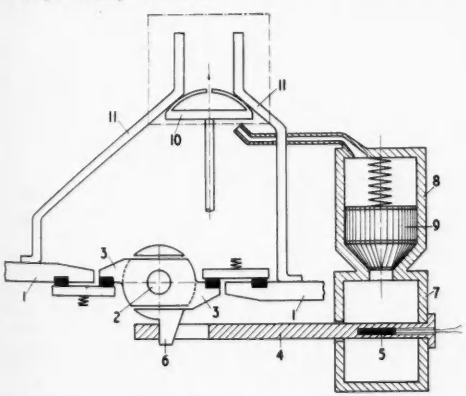

Fig. 1. **Schematic arrangement of circuit-breaker with explosive release action.**

An arrangement which can be used in practice is shown in Fig. 1. The busbars (1) are in contact with a rotatable member (3) mounted on a torsion bar (2). The torsion bar is used because, owing to its low moment of inertia, it requires only small forces for its acceleration. To cope with large nominal currents, the busbars (1) and the main contact member (3) should be adequately dimensioned, and a number of spring-loaded intermediate contacts is included in the arrangement, so as to obtain minimum inertia. The torsion bar (2), tensioned by a motor, attempts to rotate the main contact (3) in a clockwise direction, but equilibrium is maintained by the pull of the rod (4) (which contains a suitable detonator (5)), acting on the lever (6). The detonator with the rod portion surrounding it can be exploded in approximately 0·02 millisec, releasing the lever (6), thus initiating the circuit-breaking movement. The force with which the lever (6) acts on the rod (4) in the closed-contact condition is of the order of 5 tons. A force of this magnitude could hardly be released in such a short time interval by any means other than an explosion. Moreover, the arrangement is such that the forces occurring during the explosion contribute to the acceleration of the lever (6). In addition to the explosive-action system, the circuit-breaker also contains a mechanically operated release, which permits the circuit-breaking operation to take place in 3 to 4 millisec after the electrical impulse is imparted. Both systems are designed so that they may be operated separately. The mechanical release can be employed, therefore, for any normal circuit-breaking required.

Protection against flying metal is provided by the container (7), above which is a cylinder (8) with a piston (9), moved upwards very rapidly as a result of the pressure occurring through the explosion in the container. The piston expels the air from the upper part of the cylinder and thus produces a jet of high-pressure air which is available for circuit-breaking with very high currents and high voltages. It may be noted, however, that it has not yet been found necessary to use this air blast in the d.c. quick-acting circuit-breakers so far developed.

A secondary contact (10) is opened approximately 0·3 millisec after the main contact (3). This secondary contact is pressed against two rod-shaped contact members (11) by a spring (not shown in Fig. 1, and supported on one of the intermediate contacts of the busbars). When the torsion bar rotates, it releases this spring and thus initiates the downward motion of the secondary contact (10). The components in this part of the system are also made as light as possible.

ELECTRICAL FEATURES

Fig. 1 shows that, when clockwise rotation of the main contact (3) occurs, the main current path is interrupted and the entire current has to pass through the conductive members (10) and (11). This secondary path should have only a low inductance, to avoid any appreciable sparking when the main contact is disconnected, and to ensure that the flow of current is diverted very rapidly through the secondary contact. The time lag between the disconnection of the main contact and the secondary contact is important. The origins of the arcs produced by the opening of the secondary contact should move away very quickly, and a very rapid rise in voltage should be generated at the positions of the arcs. The conditions enabling such a rapid increase in arc voltage are obtained as follows:—

The arc is entirely situated in narrow gaps throughout the duration of its occurrence. The major portion of the magnetic deflecting field passes through iron, with as short a path as possible; the magnetic deflection acts at any instant only on portions of the arc which are subjected to different conditions. The air movement in the region of the arc is controlled as required. By

suitable arrangement of these conditions, it is possible to obtain high velocities for the various portions of the arc, high values of arc voltage per centimetre length, and considerable arc lengths within a narrow space, while avoiding secondary ignition between the arc paths or between parts of the arcs and the electrodes.

Disconnection of the contact members has been the subject of particularly careful experimental study, in order to determine the limiting current values at various positions of the secondary contact, and the most suitable shapes and materials to be used. It is especially important that the points of disconnection of the secondary contact should also be situated in a region of high magnetic field strength. Moreover, although the arc voltage should rise very rapidly, it should not exceed the breakdown strength of the installation.

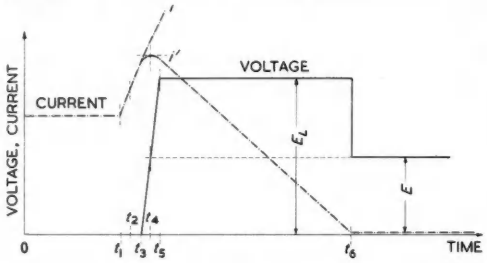

Fig. 2. **"Ideal" diagram of current and voltage variations in a d.c. circuit-breaking operation.**

The schematic diagram in Fig. 2 shows the curves of voltage and current variations which would occur in the "ideal" case of a d.c. circuit-breaking operation. Short-circuit occurs at the instant t_1, the release device responds at t_2, and disconnection occurs at t_3. Immediately afterwards there should be a steep rise in voltage up to t_5, when a maximum value E_L is obtained for the arc voltage, which should then remain fairly constant. At t_6, the current becomes zero, and the voltage across the circuit-breaking path becomes equal to the d.c. line voltage. In Fig. 2 it is assumed that the value of E_L is twice as great as that of the line voltage E. Without disconnection the current would follow the ascending curve i, but owing to the breaking operation it follows the curve i'. Disregarding the ohmic resistance of the circuit, it can be seen that the maximum value of i' is reached at the instant t_4, when the arc voltage is just equal to the line voltage. After this instant, the arc voltage should remain constant, while the current falls off along a straight line, the steepness of the drop depending on the difference between arc voltage and line voltage. The time interval between t_2 and t_4 is the critical period, but it is also important that the arc voltage, as long as the arc exists, should not fall below the line voltage; otherwise, the arc will not be extinguished.

Tests were carried out with a quick-acting circuit-breaker of this design, in which the current was generated with an ignitron rectifier system connected to a 3-MVA three-phase transformer, the time constant of the test circuit being about 15 millisec. The maximum voltage value of the test equipment was 800 V, with a maximum possible current of approximately 12,000 A, and oscillograms showed that the time from the occurrence of the releasing impulse up to the peak value of current was approximately 1·2 millisec.

Circuit-breakers of this type have now been built for 5000 A nominal current and 1000 V nominal voltage. The housing is produced as a casting of considerable mechanical strength. The apparatus has an overall height of about 38 in., and it is therefore a small and compact design. As the arc is only of short duration, the amount of wear on insulating materials and contacts is slight, so that many short-circuit breaking operations can be carried out without contact replacement. In the version used in practice, the device is combined with an isolating switch. After this switch has been cut, the detonator is replaced automatically, so that the apparatus can be put into service again very quickly.

Explosive Cut-out with Arc-Extinction System

Instead of quick-acting circuit-breakers with explosive release action, it is also possible to obtain direct disconnection of a current-carrying conductor by means of an explosive charge. Breaking times are then reduced even further, and overall construction is simplified. On the other hand, however, it is necessary to reckon with greater expenditure for the parts to be replaced after each explosion.

The protective container and the electrodes carrying the detonator can be designed in such a way that the arc resulting from the breaking of heavy currents is quenched by the gases generated in the explosion. Also, a cut-out in parallel with the detonator can be incorporated, so that the detonator will take the place of the torsion bar (2) and the main contact member (3) in a simplified version of the arrangement shown in Fig. 1. Furthermore, a fuse wire can be arranged parallel with the detonator, as shown in Fig. 3, which shows a particularly simple construction, in which (1) is the conductor and (2) the contact members. This cut-out can be used for circuit-breaking where either over-currents or reverse currents occur. The bridge (3) contains the detonator (2). When this has been exploded, the main current is diverted to the secondary path through the fuse wire (5) *via* the conductors (4). When the fuse blows, the arc produced is able to increase its length very rapidly and is thus extinguished. After a breaking operation, the entire central portion of the equipment is removed and is replaced by a new component with a detonator and fuse wire. The apparatus can be designed so that this replacement is automatic.

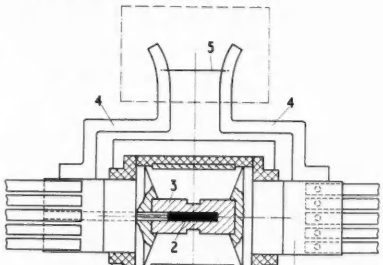

Fig. 3. **Schematic diagram of an explosive cut-out with a fuse wire connected in parallel.**

For very large nominal currents, several detonators can be connected in parallel and electrically fired simultaneously. The fuse wire (5) should be chosen of sufficient thickness to take its normal fraction of the nominal current and should be strong enough to avoid accidental mechanical damage, while on the other hand it should be able to blow with a very low value of continuous current, but only after complete disruption of the main current path.

In this arrangement, the arc voltage should also rise very rapidly and should not exceed a certain maximum value. Moreover, it should not fall below the line voltage before the arc is extinguished. The fuse wire permits operation with considerably steeper voltage rises than with the arrangement shown in Fig. 1, since in this design there are no mechanical contact members with possibilities of re-ignition. Tests have confirmed

that, with this equipment, no such re-ignition need be feared, even with the very high voltages which may occur soon after detonation, provided that no arcs are produced in the main current path.

Detonation of the explosive takes approximately 0·02 millisec. This is followed by the destruction of the fuse wire, occurring in less than 0·2 millisec with heavy currents. The peak value of the voltage surge following the sudden generation of the arc depends on the material, cross-section, length, and arrangement of the fuse wire (or wires). If, after destruction of the fuse wire, the arc develops under closely controlled conditions, its voltage will be much lower than the ignition peak. Extensive tests have shown that the time elapsing, from the triggering impulse until the arc reaches the line voltage (instant of maximum current), is about 0·2 to 0·3 millisec, i.e., only a fraction of the time obtained with the explosive-action switchgear. The circuit-breaker can also be connected in series with any normal switching device, so that switching operations may be performed without affecting the detonator and fuse wire of the equipment.

Both types of arrangement described above have their applications, and the choice of one or the other depends on the requirements of each case. Explosive charges are employed in many other technical applications and will undoubtedly be of considerable importance in electrical circuit-breaking operations.

HOLLAND

The Gloss Point of Glazes

By R. W. P. de Vries. (From *Philips Technical Review*, Vol. 17, No. 5, November 1955, pp. 153-157, 7 illustrations.)

The conventional visual determination of the gloss point of a number of glazes prepared and tested in the laboratory was found to produce widely varying results. For this reason, the objective method of determining the gloss point described in this article was developed.

In glass working, just as in metal working, specific temperatures should be strictly adhered to, in order that the glass will have the physical properties required. To characterize the type of glass in many applications, therefore, not only are the coefficient of expansion and certain other important properties indicated, but also the temperature at which the viscosity possesses the specific values required for the various phases of manufacture.

Apart from the glasses used for blowing and working into bulbs, tubes, etc., there is another group, about which much less is known, i.e., the glazes and enamels for coating ceramics, glass, and metals. The object may be to form a joint or to provide a protective or decorative finish. The coating is effected by applying to the object a thin layer of a suspension of finely ground glaze in water. The layer is dried, and the remaining grainy coating is fired in a furnace until fusion takes place. As soon as the object reaches a certain temperature during the firing process, the surface undergoes a fairly sudden transition from dull to bright. This temperature is termed the gloss point.

For the comparison of glazes, the viscosity curve is of little use. In the first place, the phenomenon in question, i.e., the smoothing out of the surface, is not a unique function of viscosity. Surface tension also has an effect and, in addition, the time factor plays a part. In the second place, the viscosity values of glaze glasses at the temperatures of firing are relatively low, and for this reason they are more difficult to determine.

The appropriate method, therefore, is to ascertain directly the gloss point of the glaze from a firing test. This can be done during firing by observing the glaze through a viewing port in the furnace wall and by noting the temperature at which the surface of the glaze is seen to become reflective by the light radiated from the walls inside the furnace, or (at temperatures below 700° C) by the light from an incandescent lamp.

When visually determining the gloss point in this way, it was found that there was sometimes an unaccountable scatter in the results. To trace the cause, an arrangement was set up for ascertaining more objectively the gloss point. The basic layout is shown diagrammatically in Fig. 1. A sample of the glaze G is placed on a slide on a chrome-iron block M and is heated in a small furnace O. By means of a small incandescent lamp F, a lens L_1, and a mirror S_1, a beam of light is directed onto the sample through an opening W_1 in the furnace; the light reflected from the sample emerges through a second opening W_2 and is directed onto a photoelectric cell P, *via* a mirror S_2 and a lens L_2. Initially, the light reflects diffusely, and the photoelectric cell therefore receives only a faint gleam. However, as soon as the gloss point is reached, the sample reflects almost as a mirror surface. The configuration of source, sample, and photoelectric cell is so chosen that the reflected beam of light falls onto the cell, which therefore now indicates a much higher luminous intensity. If the furnace temperature is gradually raised and the photoelectric current is plotted as a function of the temperature on an X-Y recorder, the resulting curve will show a sharp upward step when the gloss point is reached.

The measuring procedure is subject to a number of difficulties. The luminous intensity of the light source may vary during the recording of a curve. These variations are compensated by allowing a direct beam of light from the source F to fall onto a second, similar photoelectric cell P_0 and recording the ratio of the two photoelectric currents (reflected light/direct light) on the X-Y recorder. A more serious difficulty is the radiation from the furnace, which causes heating of the photoelectric cells. To minimize this effect, a type of selenium cell with a small temperature effect is used, and the cells are positioned lower than the furnace by deflecting the path of the light, as shown in Fig. 1.

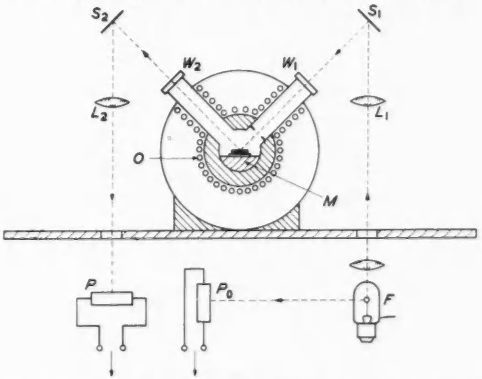

Fig. 1. **Basic layout for the objective determination of gloss point.**

Moreover, the furnace is so constructed that it operates with a minimum of power, and its radiation is therefore kept to a minimum. The slide carrying the glaze sample must contribute as little reflected light as possible. At temperatures above about 600° C, the measurement inevitably becomes unreliable, owing to the amount of light radiated by the slide and the inner walls of the furnace. This effect can be avoided by using an intermittent light source and measuring only the synchronously varying part of the light received by the photoelectric cell; at present, however, tests have not gone beyond 600° C. It is, of course, important for the temperature of the sample at every instant to be defined and known with sufficient accuracy. This is not easy to realize, as a considerable loss of heat occurs through the opening near the sample, and it is consequently difficult to obtain a zone around the sample of sufficiently uniform temperature. Again, while the temperature is being raised, the sample temperature may wholly or in part lag a little behind that at the point of measurement (the location of the thermo-element used). In view of the importance of the rate of heating, it is necessary to use a standardized heating curve to arrive at reproducible results. This is best done by automatic programme control of the furnace. Finally, the preparation of the sample should also be standardized, since variations in grain size, grain distribution, and packing can influence the measurements. So much attention is normally paid to the latter factors, which are naturally of equal importance in the visual determination of the gloss point, that the cause of the scatter in results mentioned above must be sought elsewhere. The explanation of this scatter soon became apparent from the curves recorded with the apparatus described.

The curve in Fig. 2 was obtained for a jointing glaze. With its curious dip at the beginning of fusion, i.e., just below the gloss point, it was found very readily reproducible. Because of this reproducibility, it was possible to break off the firing of different samples at various points in the critical temperature range, in order to ascertain what appearance of the glaze surface corresponded to the various points on the curve. Photographs of such samples, corresponding to points *I* to *V* in Fig. 2, show that at point *I* the sintering had only just started (the grains can no longer be blown from the slide). At point *IV* the surface had not yet become fully bright, whereas at point *V* the gloss point had evidently been well exceeded. The visually determined gloss point was found to lie at point *G*; with this glaze the visual determinations were fairly consistent.

Comparing samples *I* and *II* under the microscope, it was found that at point *II* of the curve the grains

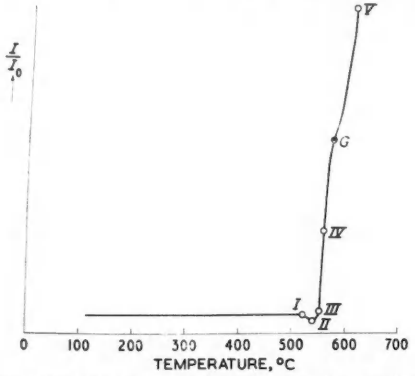

Fig. 2. **Recorded gloss curve for a jointing glaze, with the ratio I/I_0 of specularly reflected light to incident light plotted as a function of temperature.**

were just becoming rounded off at the beginning of fusion (grains sticking together), whereas this had not yet started at point *I*. The dip at point *II* can now be explained by the fact that, after entering a grain, the light has to travel further in the glaze before leaving it again, as the result of scatter. Owing to absorption in the glaze, it will have become attenuated, so that the measured reflection, which is still diffuse, is somewhat reduced.

Fig. 3 shows the much more complicated curve plotted for an experimental glaze consisting mainly of boron oxide (10%) and lead oxide (85%). Here, too, the dip is obtained just before fusion. The other large fluctuations in the reflection from the sample can be related to the physico-chemical behaviour, as follows :—After the glaze has fused to a glossy layer, it begins, at a somewhat higher temperature, to deglaze (crystallize) and therefore to re-assume a dull appearance. When the temperature is raised still higher, the minute crystals formed either fuse again or dissolve in the residual glass mass. A moment later, the mass deglazes once more, after which final and real fusion takes place. It is hardly surprising that this chain of events gives conflicting results in the visual determination of the gloss point. An observer who conscientiously records the very first signs of brightening has the best chance of arriving at a reproducible result, but the mere reproducibility of this particular result is of little consequence; the important thing is to recognize the deglazing effects, since it is upon these that the glaze will have to be rejected for most applications.

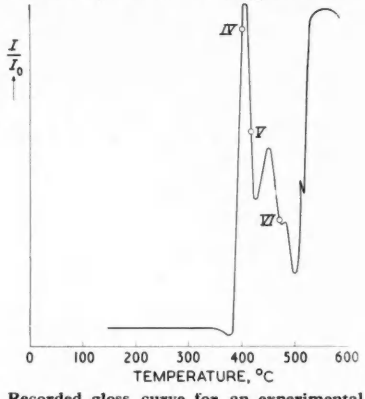

Fig. 3. **Recorded gloss curve for an experimental glaze, with a heating rate of 2° C per minute.**

In addition, the curve in Fig. 3, which was based on a heating rate of 2° C per minute, was found to be readily reproducible, since, although it was displaced as a whole towards somewhat higher temperatures when the heating rate was increased, no appreciable changes in its features were noted. It was therefore again possible to break off the firing process at certain points on the curve, in order to confirm the deglazing effects by means of X-ray diffraction analysis. Analyses were carried out for points *IV*, *V*, and *VI* on this curve. For point *IV* only a glass phase was found (no sharp diffraction lines); for point *V* the preparation was found to have, in addition to the glass phase, a crystalline phase of β-$Pb_4B_2O_7$; in point *VI* this crystalline phase had disappeared, and in its place were identified crystals of α-PbB_2O_4. In this way confirmation was found for the deglazing as such, and for the difference between the two deglazing processes.

As the foregoing shows, the objective determination of the gloss point can be a valuable means of investigating and eventually, perhaps, of mastering the composite physico-chemical processes taking place during the firing of glaze powders.

The Properties and Applications of Silicones

By D. C. R. MILLER. (From *The Engineering Journal*, Vol. 38, No. 10, October 1955, pp. 1339-1349, 12 illustrations.)

In the twelve years since their first commercial production, the use of silicones has spread into almost every field of engineering. The following survey should provide something of interest to every engineer, irrespective of his particular field.

THE term " silicone " has come to be applied to all the polymers based on alternate silicon and oxygen atoms, or siloxane linkages, with organic groups attached through carbon to the silicon. The siloxane structure, which is responsible for the durability, oxidation resistance, and chemical inertness of glass and quartz, is what imparts to the silicones their remarkable properties.

An even broader use of the term " silicone " may be expected in years to come to cover silicon-carbon, silicon-nitrogen, or other linkages replacing the siloxane bonds in whole or in part. By varying their molecular arrangement, composition, and degree of cross-linking, these silicon-containing polymers can be made as fluids, rubbers, or resins in an immense variety of types.

THE SILICONES AS FLUIDS

Methyl Silicone Fluids:—

The silicone fluids in commonest use at present are the methyl silicones, usually depicted as straight-chain polymers based on a siloxane backbone with two methyl groups attached to each silicon atom, and chain lengths from two to many hundreds or even thousands ; they give fluids varying in viscosity from that of water to that of asphalt. These methyl silicone fluids are about 60% inorganic and thus exhibit many of the properties of their quartz parentage and of the family in general.

Excluding the volatile low polymers of the series, the methyl silicone fluids are inert, heat-stable, non-oxidizing, and non-volatile. They have low freezing and high boiling points, and change viscosity extremely little with temperature or under shearing conditions. They are soluble in most aromatic and chlorinated hydrocarbons, but are incompatible with most organic polymers. They have extremely low surface tensions and a correspondingly great affinity for wetting metal and glass surfaces. They are highly water-repellent, have excellent dielectric properties, and have much greater compressibility than organic fluids. On one or several of these properties depend their multitudinous uses.

Typical medium-viscosity fluids have freezing-points around −55° C, boiling-points over 250° C, and a volatility of less than 2% after 48 hours of heating at 200° C. Their glass-like non-volatility is further shown by the fact that they may be heated to 150° C for 12 months with a weight loss of only 0·5%. A typical heavy mineral oil would show a 15% weight loss after one month.

These fluids show less change in viscosity with temperature than any others. Compared with a typical S.A.E. 30 motor oil, which increases from 6·6 centistokes at 120° C to 70,000 centistokes at −25° C, a methyl silicone fluid, having the same room-temperature viscosity as the petroleum oil, increases only from 75 centistokes at 120° C to 1300 at −25° C.

This behaviour is thought to result from the fact that individual molecules of the fluid are not straight chains but are helical, with 6 or 7 silicon atoms per turn. On heating, thermal agitation increases the molecular spacing, thus tending to reduce viscosity ; however, the coiled molecules lengthen and thereby exert an opposing effect.

The lubricating properties of these fluids, while satisfactory for many conditions of loading and combinations of bearing metals, are poor under extreme pressures and with sliding ferrous surfaces. This is believed to be related to the helical form of the molecules, which permits the silicone film to be easily displaced. This helical form also makes it easy to visualize why the methyl silicone fluids are so compressible.

Fig. 1 shows the comparison in compressibility between a range of methyl silicone fluids and a typical mineral oil. Ag 15,000 psi the organic oil is compressed 4·7% by volume, and the methyl silicone fluids from 7·8 to 10·4%, the lower-viscosity polymers having the highest compressibility. The centre line shows values achieved for a medium-viscosity silicone fluid specially developed for maximum compressibility.

The flat temperature-viscosity slopes of the methyl silicone fluids and their resistance to shear breakdown have led to their widespread use in overload relays, accelerometers and recorders, torsional vibration dampers for internal combustion engine crankshafts, dashpots, and shock absorbers.

Because they are heat-stable, oxidation-resistant, and non-volatile, as well as incompatible with most organic polymers, they are ideal release agents for many types of moulding operations. They do not decompose or carbonize when applied to hot moulds, and so reduce mould maintenance and improve surface finish. For this purpose they are used neat, or as water-dilutable emulsions, as grease-like compounds, or solvent dispersions. Their low surface tension makes them effective in concentrations as low as 0·25%.

In the rubber industry their use has become universal for tyres, heels, soles, floor tiles, and mechanical goods. In the plastics industry they are used to release all types of mouldings—polystyrene, melamine, phenolic, poly-

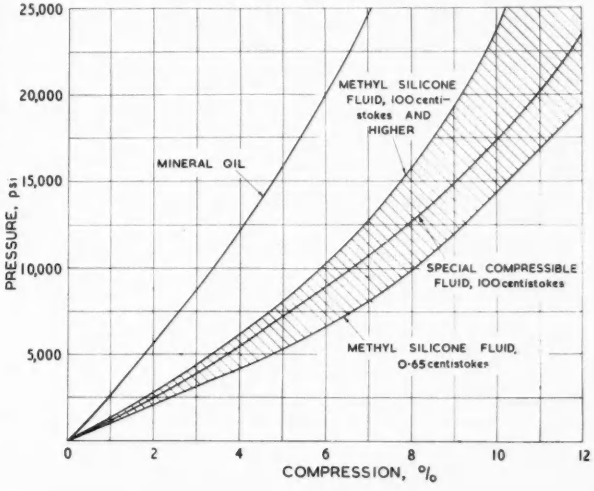

Fig. 1. **Comparative compressibility of silicone and organic fluids.**

ester, and epoxy resins. In the plywood industry they prevent build-up of adhesive on platens and cauls and are used to lubricate edge-gluer chains and saws. In the food industry they facilitate heat-sealing operations on all types of film wrapping materials and prevent build-up and adhesion of foods to cooking coils, tanks, and kettles. In the metal-casting field they improve release of zinc and aluminium die-castings, zinc and silver ingots, and brass ingots poured in cast-iron moulds.

Silicone release agents have contributed towards making the shell-casting process practicable by permitting the consistent clean, easy release of the sand-resin shells from automatic shell-moulding machines. Production of parts to close tolerances is possible, because of minimum build-up on the metal patterns.

Their properties of compressibility are already being utilized in liquid spring devices involving high-force, short-stroke applications, such as aircraft landing gear and dies for forming and punching sheet metal. Such units make possible great savings in weight and space. Liquid springs have the further advantage of being able to operate at high speeds without resonant frequencies.

The properties of inertness, non-compatibility, non-volatility, and water-repellence are now being utilized in most furniture and automobile polishes, which have a high gloss and provide a weather-resistant and non-staining surface. The same properties are being used in various cosmetic preparations, such as hand creams, ointment bases, and burn unguents. Their excellent dielectric properties, unchanged over a wide frequency range, make them useful as liquid dielectrics for condensers, capacitors, and small transformers designed for maximum reliability over a wide temperature range.

These silicone fluids, when combined with inorganic fillers, can be made into grease-like compounds with many useful properties. One such material is used as a non-melting, non-drying, moisture-proof dielectric seal for ignition and electrical systems, and as a lubricant and preservative for automotive rubber parts. Another similar silicone compound is used as a valve and pump-packing lubricant in systems handling hot water, steam, many dilute and concentrated acids and alkalis, and many corrosive gases, over a temperature range from -40° to 250° C.

Yet another methyl silicone compound is an extremely active and versatile defoaming agent for the majority of aqueous and non-aqueous foamers. It is equally effective in oils, asphalts, varnish cooking, rubber latices, detergents, jam, tallow, and glue—usually in concentrations of less than 40 parts per million. This compound is also supplied as an edible emulsion and as an aerosol spray. Its efficacy is thought to be related to the combination of low surface tension and incompatibility effects at the gas-liquid interface of the foam. The same properties make the fluids useful as paint additives, to reduce pigment floating and "silking," to improve flow-out, and to impart mar-resistance.

Methyl-Phenyl Silicone Fluids:—

In the methyl-phenyl fluids, phenyl radicals are partially substituted for methyl, to give methyl-phenyl silicones with varying proportions of methyl to phenyl. These fluids become progressively more heat-stable as the amount of phenyl is increased, and exhibit better lubricating properties and greater compatibility with organic substances.

These materials are used as extreme-range lubricating oils and as heat-transfer media in heat treating and high-temperature baths. The medium-methyl phenyl fluid may be heated to 200° C for 12 months with a weight loss of only 14·6%.

By combining suitable fluids of this type with lithium soaps and thickening agents, such as carbon black, silicone greases may be made which will operate within the range of -100° F to 500° F, or higher in intermittent service. These greases are very satisfactory for ball- and roller-bearing lubrication for high- or low-temperature service. Their oxidation resistance makes possible permanent lubrication at normal temperature.

Under identical conditions the silicone grease may be expected to have ten times or more the life of organic greases. These greases are used in various meters and instruments exposed to extremely low temperatures, and in electric-motor and fan bearings, textile driers, oven conveyors, kiln-car bearings, and similar extreme services. Savings in maintenance cost and downtime justify their much higher cost.

Other Silicone Fluids :—

Much effort has recently been expended in producing silicone fluids with better lubricating properties in sliding friction between ferrous surfaces. The aircraft gas turbines now being designed for even modest supersonic speeds need a lubricant with an operating range of -65 to 800° F. Silicone fluids with halogenated organic groups give promise of having the necessary lubricating properties. It is unlikely that such an operating span as this will ever be approached by non-silicone lubricants.

Considerable work has also been done towards developing a non-inflammable aircraft hydraulic fluid by blending a methyl silicone with a halocarbon oil. This product appears to have better lubricating properties in hydraulic systems than standard mineral oils ; it will operate for hundreds of hours at 500° F, and does not swell organic rubber seals.

Methyl and phenyl radicals, alone, in combination, or modified, are those mainly used in the commercial silicone fluids to-day. When larger organic groups are used the resultant fluids suffer reduced heat stability and lose more and more of the special properties deriving from the central siloxane structure. Nevertheless, at normal indoor or outdoor temperatures, their resistance to weathering and sunlight and their durability may still be far superior to those of organic polymers. These materials may well find uses as water-repellents.

Silicone fluids, having reactive organic radicals such as hydrogen, allyl, vinyl, or many others, may be prepared and have interesting and useful properties. As these are converted to resins by application of heat or exposure to air, they will be covered under resins, as also will the reactive water-dispersible types.

The Silicones as Rubbers

Silicone Gums :—

When the chain length of the methyl silicone fluids is sufficiently lengthened, they become elastomeric gums, which may be compounded with inorganic fillers and caused to cross-link by heating with a "vulcanizing" agent to form a whole new class of materials, the silicone rubbers. Because of the close resemblance between the silicone gums and the silicone fluids the resulting silicone rubbers possess many of the same properties, i.e., they are unaffected by extremes of temperature, weathering, and attack by most chemicals ; they are water-repellent ; and they have good dielectric properties. They look and feel like organic rubbers but retain their rubbery properties up to 600° F.

The silicone gums may be varied in molecular weight and composition, just like the fluids. The gums with lower molecular weight are used for compounding into putties or pastes, with or without vulcanizing agents. One such non-vulcanizing form is "bouncing putty," which may be regarded as a bridge between the fluids and the rubbers. It has the anomalous properties of flowing like a viscous liquid, bouncing like rubber, and shattering like a brittle solid at a sharp blow.

Other types of paste may be made in various degrees of fluidity for different methods of application—knife-coating, vacuum-impregnating, dip-coating, or caulking. These may be converted to rubbers without significant shrinkage by heating, since they contain no solvent.

No latex forms are yet available, but the coatings can be applied from solvent dispersions.

A recent important advance has been the development of room-temperature vulcanizing pastes. These are supplied as two components which, when mixed together in equal amounts, will cure at room temperature overnight to silicone rubbers.

When gums of higher molecular weight are used and compounded with fillers, vulcanizing agent, and possibly other additives, crude silicone rubbers are produced, analogous with organic rubber crepes. The most generally used gums are methyl silicone polymers. These yield rubbers with brittle points down to −80° F. Where brittle points down to −130° F are needed, methyl-phenyl gums are used. Special gums are also available for producing low-shrinkage stocks, and low compression set.

The vulcanizing agents normally used for silicone rubbers are strong organic peroxides, such as benzoyl peroxide. These materials decompose when heated, liberating free oxygen, which reacts with the methyl groups on adjacent polymer chains. Cross-links are formed at these points and the rubber-like quality quickly develops.

There has recently been developed a vinyl-modified methyl silicone gum which is compatible with many organic rubbers and can be co-vulcanized with them, using the conventional sulphur and sulphur-containing vulcanizing agents. This new polymer is heat-stable up to 200° C and, when blended with natural gum rubber, butyl, or neoprene, will improve heat stability, resistance to weathering, corona and ozone, and improve low-temperature flexibility.

Silicone Rubbers :—

By the proper choice of the quantity, quality, and combination of fillers, vulcanizing agents, and gums, the properties of silicone rubbers can be varied widely. When certain properties are required to the maximum extent it is necessary to compromise on other properties.

The various grades of fine silica commercially available are the most effective reinforcing fillers, and of these fumed silica (silica soot) is outstanding. Other inorganic fillers, such as calcium carbonate, iron oxide, titanium dioxide, and zirconium silicate, may be added, depending on the properties desired, colour, and type of fabrication. Mercuric and cadmium oxides may be used as compression-set additives.

Probably the most important property of silicone rubbers is their resistance to heat-ageing, inasmuch as these materials can remain in good condition after 30 weeks at 300° F and are useful engineering materials at temperatures up to 500° F.

At the opposite end of the scale, the extreme-temperature grades of silicone rubber, with brittle points of −130° F or lower, retain their rubber-like properties down to −100° F with little change, whereas organic rubbers, though they can be compounded for brittle points of −65° F and lower, are very much stiffer and less resilient at sub-zero temperatures. Furthermore, silicone rubbers are unaffected by outdoor weathering.

Although silicone rubbers can be compounded with tensile strengths close to 2000 psi and elongations up to 850%, such stocks at present have limited heat stability ; values of 800 to 1100 psi tensile and 250 to 300% elongation are more representative. These properties, in the general-purpose stocks, are well maintained over the wide operating range.

Silicone rubbers compounded for optimum electrical properties have a dielectric strentgh of about 550 V per mil in $\frac{1}{8}$-in. thickness, and retain their dielectric properties at high temperatures and high frequencies. Special cloth-coating stocks, with a dielectric strength on 0·010 cloth of 1200 V per mil, showed no loss in dielectric strength after 800 hr at 480° F, or 200 hr at 600° F.

When compounded with silica soot, silicone rubbers with very low moisture absorption can be made. These stocks retain both electrical and mechanical properties after 4 months immersion in boiling water. In a test for corona resistance on 5-mm ignition wires at 14,000 V, the organic rubber covering broke down from corona cutting in 30 minutes ; the silicone rubber was still unaffected after 12,000 hours.

The silicone rubbers are resistant to a variety of chemicals and some, but not all, hot oils. Certain stocks are resistant to hot water and saturated steam at pressures below 100 psi. All are badly swelled by most volatile hydrocarbons, such as petrol, kerosene, and carbon tetrachloride. Usually, however, they recover their properties on removal. At present, the relatively high cost of silicone rubbers limits their use to applications in which organic rubbers are totally unsuitable.

No extensive uses have yet developed for the silicone " bouncing putties," though their use in a combination slip clutch and flexible coupling has been proposed.* As cloth-coating materials, the silicone rubber pastes are used in many gasket applications. A typical example is in aircraft-engine rocker-box gaskets in contact with hot engine oil at temperatures up to 450° F. Similar coated glass cloths are used in aircraft hot-air ducts for heating and de-icing, as diaphragms in pumps and valves exposed to heat or cold, etc.

Electrical insulating tapes, fully or partially cured, are made from these materials and used in the hot pressing of field and armature coils in diesel-electric locomotive motors, and as cable-wrapping tapes. The pastes are used alone for sealing, caulking, and bonding. They may also be used for encapsulating and potting electronic components, coils, or small transformers, through the development of an improved type that will vulcanize rapidly in thick sections without sponging, or the need for a confining mould. For components which might be damaged by the heat of curing, the room-temperature vulcanizing pastes are used.

Silicone rubber mouldings are used as flexible boots and seals on aircraft limit switches, and as heat-resistant and moisture-excluding covers for automobile sparking plugs. Aircraft-engine push-rod housing seals remain pliable after more than 1000 hr in contact with hot engine oil, and greatly reduce maintenance cost. In the form of O-rings they are used extensively in aircraft gas turbines.

In the lower cylinder liners of locomotive diesel engines they are used in contact with both hot water and hot oil, giving nine times the life of organic rubber O-rings. Similar O-rings are used in certain automobile automatic transmissions. Silicone-rubber-covered rolls are used in embossing thermoplastic films, and their heat-resistant and non-sticking properties utilized in press pads for heat-sealing and in belts for conveying sticky foods.

As extrusions, silicone rubbers are used for sealing the oven doors of domestic stoves to withstand hot cooking fats and temperatures approaching 500° F. In aircraft bomb-bay doors and cockpit-canopy seals they will remain flexible at −100° F. Sponged silicone rubber is used as a cushion seal between aircraft flaps and wings.

Extruded over wire, silicone rubber is used in the waterproof ignition systems of army vehicles, and as a general-purpose high-temperature lead wire for motors, ovens, and outdoor flood lights.

The sulphur-vulcanizable silicone gums are expected to be useful in extending the low-temperature range of organic rubbers in such applications as fan belts and tyres for Arctic vehicles ; in extending the high-temperature range of, for example, hot conveyor belts or landing-wheel tyres for supersonic aircraft ; and in

* See *The Engineers' Digest*, Vol. 15, No. 8, August 1954, pp. 315-317.—Ed. E.D.

wires and cables to improve resistance to ozone, corona, and weathering.

THE SILICONES AS RESINS

By a variation of molecular arrangement, silicones can be produced with a greater degree of cross-linking than the fluids or rubbers. These polymers, normally supplied as solvent solutions, will further polymerize either by heating, or in particular cases by air drying, to form silicone resins or varnishes. The physical properties of these resins may be altered by varying the ratio of organic radicals per silicon atom, i.e., the degree of cross-linking, and by varying the organic radicals themselves.

Certain resins of low molecular weight are compatible with organic resins and may be cold-blended with them to up-grade their properties. Still other types may be made by co-polymerizing with organics such as alkyds or phenolics for the same purpose. Such types are becoming more important.

Where some property other than heat stability is sought, e.g., water-repellence, resins with reactive organic groups may be used. These will develop their properties either by relatively mild heating (e.g., 5 min at 300° F) or at room temperature through oxidation, reaction with absorbed surface moisture, or CO_2 from the air. As with organic resins, properties may also be modified by the addition of silicone fluids or gums to act as plasticizers or to confer special properties, such as adhesion.

The curing temperature or time of all the silicone or modified silicone resins can be reduced by addition of accelerators or driers, usually fractional percentages of organo-metallic compounds such as zinc naphthenate. These may affect heat life and reduce shelf life.

The primary properties of the silicone resins are heat stability, resistance to oxidation and weathering, and excellent dielectric properties. By continuing improvements in composition, the heat life of the best silicone resins has been greatly extended; the earlier resins produced had a life, as measured by crazing of films 2 to 3 mils thick, of about 300 hours at 250° C; resins with equal or better physical properties are available to-day with 3000-hr lives at this temperature. The corresponding life of the most heat-stable phenolic-alkyd organic resins is about 5 hr.

Dielectric strength is equal to or better than that of of the best organic resins and is maintained under extremely humid conditions, because of low moisture absorption. Dielectric properties are also maintained even at extreme high frequencies, as is dielectric life at high temperatures, since the decomposition product, silica, continues to insulate, rather than conduct like carbon. Dielectric life at 200° C is over 100 times that of organic resins.

All the silicone resins are water-repellent, but this behaviour in contact with water as a liquid must be carefully distinguished both from water absorption and transmission of water vapour. Thin films of silicone resins (as also silicone fluids and rubbers) have high rates of gaseous diffusion, which, if undesirable, may be reduced by the addition of mica flakes.

Certain of the silicone resins, when applied and thoroughly cured on metal surfaces, have pronounced and semi-permanent release properties for most organic materials. The solvent resistance of even fully cured silicone resins is, in general, poor, but resistance to acids and dilute alkalis is good.

Electrical Applications:—

Both the all-silicone and the modified silicones are used in high-temperature electrical insulation. The resins are used as dipping varnishes and as coatings for glass cloth, tapes, and sleevings, and glass-served magnet wire. They are used as bonding agents for rigid and semi-flexible laminates of glass cloth, asbestos, and mica. A recent important advance has been the development of modified silicones as bare wire enamels, with toughness and solvent resistance comparable with those of the best organics.

The adoption of silicone insulation for electric motors is becoming more widespread, particularly for motors operating in moist or corrosive atmospheres or in high ambient temperatures; for motors subject to heavy overload or starting loads, or rapid reversal; and for motors where size and weight must be kept to a minimum. The life and reliability of solenoid and induction heating coils are similarly increased by the use of silicone insulation.

Protective-Coating Applications:—

Silicone resins similar to the electrical resins can be pigmented and used as protective coatings to span the gap between the less expensive organic paints and the costly but brittle vitreous enamels. The base resins may be either soft and flexible, or hard and tough, depending on the application.

Unmodified silicone paints are used for extreme-temperature applications in the range of 500 to 1500° F, for application to stacks, mufflers, and other high-temperature surfaces exposed to the weather. High loadings of aluminium powder in conjunction with a soft, flexible resin result in maximum heat and weather resistance.

Resins of this type are used in aircraft gas turbines in pigmented form to protect combustion cans and as clear films to protect compressor blades at temperatures up to 570° F. In refinery-stack applications paints of this type have demonstrated an outdoor life of 18 months where organic paints failed after a week or two.

For less severe high-temperature requirements, modified silicone enamels of either baking or air-drying types may be used. The base resins, usually alkyds, may be modified either by cold blending with specially compatible silicone resins, or by cooking with reactive silicone intermediates, which co-polymerize with the alkyd resin components. The cold-blending types are the most versatile, and as little as 10% addition may be enough to give substantial improvements in gloss retention, and weather and heat resistance. These types are compatible with the common organic resins. They are used on space heaters, or domestic appliances and incinerators, replacing the more expensive vitreous enamels.

The air-drying silicone-alkyds are opening up some interesting fields both as clear varnishes with superior weather resistance, and as paint vehicles for general-purpose industrial maintenance finishes.

Air-drying silicone phenolics are too new to have found extensive application as yet. As they have excellent water resistance and very low rates of water-vapour transmission, they are useful in marine varnishes and paints, and as insulating protective coatings in, for example, printed circuits.

Silicone Laminating Resins :—

Special silicone resins have been developed for laminating with glass cloth to form rigid sheets, rods, or tubes with excellent strength and electrical properties at high temperatures and high frequencies. These laminates are used for coil forms, slot sticks, and similar electrical applications. Of special interest to the plastics industry is the recent development of a silicone low-pressure laminating resin which, in combination with glass-fibre reinforcing materials, is used to make low-pressure laminates with great strength at high temperatures.

These laminates are outstanding in their strength-to-weight ratio, and at 500° F are superior to most light metal alloys. They are not damaged by brief exposure to temperatures up to 900° F. Their properties suggest structural uses in high-speed aircraft and guided missiles, or for use in gas-turbine compressor blades, because of freedom from fatigue failures.

Silicone Moulding Compounds :—

Using similar resins, glass-reinforced silicone moulding compounds can be made for compression or transfer moulding by standard methods. The resulting parts retain their electrical and physical properties at temperatures over 390° F. The heat-distortion point is above 930° F. Potential applications include switches, connector plugs, coil forms, and moulded parts for aircraft ignition systems. They may also be used as high-strength heat-isolating materials, as in aircraft brake-shoe assemblies.

Silicone Foam Resins :—

Silicone resins are also available which, in combination with blowing agents and accelerators, may be expanded and cured to rigid, low-density, unicellular foams. These are supplied as dry powders containing all the ingredients necessary to permit foaming in place. Foams with a density of 14 lb/cu ft retain much of their original compressive strength after 200 hours heating at 500° F, have a heat-distortion point above 700° F, are not damaged by brief heating to a dull red heat, and are non-inflammable. The high price of these foams will, however, limit them for the time being to special uses.

Silicone Release Resins :—

Certain silicone resins, when applied as clear coatings to metal surfaces and thoroughly cured, have the same release properties as some of the silicone fluids, but are semi-permanent. The largest use for such materials is on bread and bun pans in bakeries. Despite baking temperatures around 500° F, a single coating may last as long as 200 bakes, eliminating the cost and smoke of pan grease. The same treatment is effective on pans for cooked meats, frozen-food trays, and in various rubber, plastic, and hardboard moulding operations.

Silicone Masonry Water-Repellents :—

The highly water-repellent properties of the silicones, coupled with outdoor durability, have led to special types for application to above-grade masonry. These should be flooded onto the surface from a minimum 5% solvent solution, which penetrates to a depth of $\frac{1}{8}$ to $\frac{1}{4}$ in., and on drying forms a durably water-repellent surface. The cost of this dilute resin treatment is low, and a single saturating coat should be effective for 5 or 10 years, or more. The coating is invisible and does not prevent the masonry from breathing.

Water-Soluble Reactive Silicones :—

Similar results may be obtained from water-soluble sodium salts of silicone resins, diluted in water and sprayed onto the surface being treated. The silicone salt converts and develops repellence on exposure to air and drying. Not only masonry but paper and other organic materials can be similarly treated. When applied to soils or clay, seepage into the ground and rain erosion is prevented. Whether this behaviour will be utilized in highway and irrigation-ditch construction remains to be seen. The concentrated salts are highly alkaline and require some care in handling.

Chemically different silicones with reactive organic groups, which may be directly dispersed in water without objectionable alkalinity, are also beginning to be available. These may assume importance as protective treatments for glass, masonry, and other surfaces. A non-oily, water-repellent film is developed instantaneously after spraying, flooding, or dipping in solutions containing from 0·01 to 0·1% silicone. The film is not removed by steam, detergents, or solvents.

Glass-Treating Resins :—

It has been known for many years that polished glassware is greatly weakened by scratching or similar damage to the surface. Recently, it has been found that, when a reactive silicone polymer is sprayed onto the virgin surface of newly moulded glass containers at the exit end of the annealing lehr, the heat of the glass and the lehr will cure it and bond it to form a permanent lubricating surface. Treated glass containers have only 10% the breakage rate on filling lines and much lower shipping losses. This treatment is of interest in prolonging the life of returnable bottles.

For some years pharmaceutical manufacturers have been using various types of silicones for treating glass vials to make them water-repellent and free-draining inside, and thus avoid waste of valuable antibiotics. The new treatment will provide this as an incidental advantage, if containers are sprayed inside and out.

Textile- and Paper-Treating Resins :—

Special silicone resins have been developed for application to textiles to make them water-repellent. These are methyl hydrogen silicone polymers which, when heated in the region of 300° F for a few minutes, give off the hydrogen and cross-link to form a resinous envelope round each filament of the fabric, durably bonded in place and resistant to repeated launderings and dry-cleanings.

All types of natural and synthetic fibres can be treated, usually from emulsions of the silicone resin and an accelerator. As only 1 to 2% silicone pick-up, based on fabric weight, is needed, and these particular resins are among the cheapest offered, the cost of the treatment for most fabrics is very low.

By using similar resins and increasing the silicone addition to 4 or 5%, woven woollen fabrics or blankets can be quickly and effectively shrink-proofed, without the usual harshening or weakening. Such materials can withstand ten 30-min commercial launderings at 140° F, with no significant felting shrinkage.

Identical silicone resins are used, applied in much the same way, to make paper or parchment non-adhesive. Again, 1 or 2% addition is sufficient for the purpose. Typical uses are for packaging sticky foods and interleaving adhesive tapes.

Leather Water-Repellents :—

A special type of silicone is now available for application to leather. For optimum results a 15% addition is applied from a solvent solution during the tanning process. Whereas untreated leathers wet through in a wet-flex test in 100 to 200 flexes, silicone-treated chrome-tanned leathers average 10,000 to 30,000 or more flexes before wetting through. The vapour transmission of the leather is not impaired and low-temperature flexibility is improved. The leather also becomes more resistant to alkaline salts, cutting oils, and chemicals, and is 20% lighter than fat-stuffed leathers. Other types are under development as dry-cleanable water-repellents for garment leathers.

Silicone Adhesives :—

A pressure-sensitive adhesive has recently been developed having such remarkable tack that it will stick to even such non-adhesive materials as polyethylene, Teflon, or silicone-varnished glass cloths. This material has an effective range from −55° C to 250° C. It is weather-resistant and will stick to cold or wet surfaces, or even under water. Tapes treated with this material are used for high-temperature electric insulation and for weather- and water-resistant low-temperature wrapping and sealing applications.

Conclusion

While many of the uses of silicones depend on incompatibility, they can also be made highly compatible. In fact, the trend seems to be towards the increasing development and utilization of types which, by combining with organic materials, may be used to upgrade their durability and extend their temperature range.

It should, however, be borne in mind that silicones have their limitations and should not be regarded as "cure-alls," though it is true that, in the medium-temperature field, many difficult design problems have already been overcome by their use.

U.S.A.

Advances in Tube Swaging

By E. Tollefsen and L. Pickrell. (From *The Tool Engineer*, Vol. 35, No. 3, September 1955, pp. 151-154, 12 illustrations.)

Because of the important role of tubing in aircraft manufacture, new swaging methods have had to be developed constantly to meet design and production requirements. For example, one of the latest improvements involves the use of helically fluted dies which are rotated in the headstock of a turret lathe as the tubing is advanced in the turret. This tooling promises many improvements over previous types for current production requirements.

As applied to metal tubing, swaging consists of forming the tube to a smaller diameter in the desired area, generally an end, by subjecting the tubing to forming forces. The swaged section must remain circular. For fluid connections, one tube is usually swaged and a nut slipped on. The tube is then flared to hold the nut and to secure a leak-free seal.

Tube swaging became necessary to meet the changing requirements in aircraft construction. Especially significant from this viewpoint was the B-17 bomber, both in terms of emphasis on production quantities and the large number of swaged tubes per aircraft. Thus, for instance, more than 1000 swaged tubes were required for fluid lines in the B-17. Since then, designs for de-icing equipment have shifted from fluid to hot-air systems, resulting, of course, in different requirements for tubing. In addition, current aircraft designs involve many more swaged tubes for control-system applications than previously.

It may be said that the production development of tube-swaging methods initiated with the B-17, in which swaging appeared to offer the most reliable means of providing tubing connections. Copper was the material involved, since aluminium and stainless-steel tubing were not yet an important factor in aircraft design. Production tubes were first swaged by an impact process of pounding the copper tubing into a steel die with a hammer. This method, however, was far from satisfactory because of the excessive production time involved and the high rejection rate. Attempts were made in the drop-hammer shop to form swaged tubes between two hammer dies, but this method was abandoned because of severe tube marking at the die parting line.

Consideration was next given to the idea of modifying a spinning lathe so that it could be used to swage tubing. By this process some 600 tubes were swaged. The tube was set up to rotate by clamping it in a jaw chuck on the headstock. The lathe was modified at the tailstock to hold the die and to allow it to be advanced onto the tube. Although this method was an improvement over those previously used, the operation was still too costly. Scrap rate was high, with too many tubes twisted, scarred, and distorted from being clamped in the three-jaw chuck. However, the process did produce the desired results. Additional problems appeared as aircraft design changed to incorporate stainless-steel and aluminium tubing.

A good solution was found when a turret-type lathe was tried out for possible adaptation to the swaging operation. This equipment proved successful when

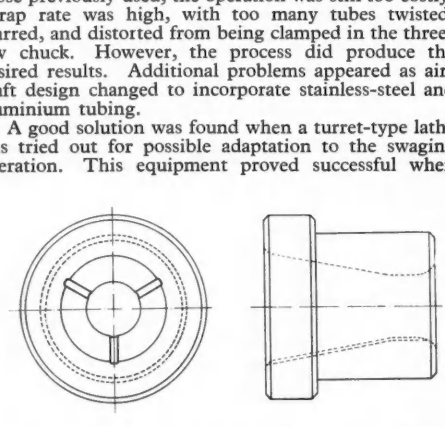

Fig. 1. **Straight-flute swage die, with flutes extending through the die.**

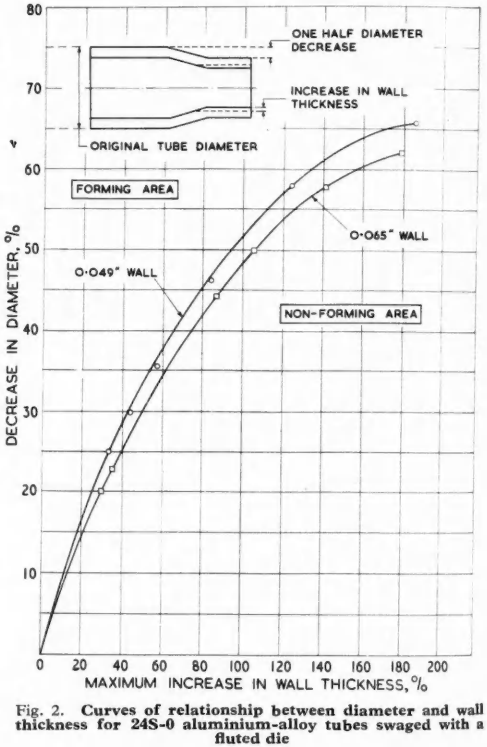

Fig. 2. **Curves of relationship between diameter and wall thickness for 24S-0 aluminium-alloy tubes swaged with a fluted die**

the swaging die was rotated on the headstock while the tube was held in the turret and advanced into the rotating die by the turret operation mechanism. Since then, developments have been concerned primarily with improving the design of swage dies for use in this set-up.

A smooth swage die of Micarta was the first successful die to be used in the turret-lathe operation for swaging aluminium tubes. The die material was subsequently changed to heat-treated steel. The hardened steel die proved a definite improvement over Micarta because of increased die life and better dissipation of the heat generated during the forming operation.

To discover a satisfactory die material for swaging stainless steel presented another problem. Micarta dies were again used at first, but were found to have limited life. Heat-treated steel dies were next tried, but were unsatisfactory because of galling and scoring of both die and tube. Several bronzes were tested, but with these dies life was again limited to a few parts. Finally, half-hard navy brass was selected as the best die material for stainless-steel, as it produced approximately 500 swaged tubes before requiring replacement.

Smooth swage dies, which were used up to 1942, were limited to 20% tube reductions, as the friction

inherent in the die design prevented aluminium tubing ifrom being swaged to any greater degree. For greater reductions, both anneals and additional dies were required. To overcome the restrictions of the smooth die, a die was designed with flutes in the straight portion of the die. All combinations of numbers of flutes from two to seven were tried, but three flutes were finally chosen as the optimum. This die appeared to reduce the friction forces, and reductions up to 40% could be accomplished in one die without resorting to anneals.

When hot-air ducts or electrical equipment replaced fluid lines for de-icing, and with the advent of high-speed aircraft using booster systems and other devices for operating control surfaces subjected to high aerodynamic loads, a further design evolution involving tube swaging has taken place since the war. Of late, the major request for swaged tubes has arisen from the necessity of forming actuating-rod ends to effect a suitable connection with end fittings. As it now appears, tubes will continue to be swaged for fluid-line applications, but the concentrated development effort will be directed towards providing the best structurally efficient actuating rod possible.

In another approach to a cost reduction of the tube-swaging operation, different methods of tube swaging are being tested experimentally. For instance, an attempt was made to swage tubing in a standard cable swaging machine. Although this operation succeeded in swaging the tubes, they were sub-standard, owing to a non-circular inside diameter and a lack of consistent concentricity between the tube and its swaged end. It is believed that this undesirable condition was caused by insufficient support of the tube beneath the hammers of the cable swaging machine. Again, an effort was made to swage tubes in the turret lathe with an adjustable swage die, but this experiment also failed to produce a swaged tube which was sufficiently round for production.

After these two failures, attention was directed towards redesigning the production swage die used so successfully for tube junctions. In the opinion of tool engineers associated with this operation, reducing friction was the important problem in the new application. Subsequently, a die was developed to change the configuration of the transition area by extending the flutes the full length of the die (Fig. 1).

The effect of the new flutes is outstanding, permitting swage reductions up to 65%, using two dies and without anneals, compared with the previously accepted limit of 40%. The flutes appear to allow a freer circulation of oil and provide less rubbing area. Tests have shown that they grip the material in such a manner as to "knead" it as the die rotates. In addition, a substantial tube thickening, which can be depended upon in the swaged end, is accomplished. This is of value, for example, in actuating-rod applications. Fig. 2, which is based on tests which include tubes of 2 in. o.d. maximum and 1 in. o.d. minimum, indicates what can be accomplished by using this die to swage tubing of 24S-0 aluminium alloy (4·5% Cu, 1·5% Mg, 0·5% Mn).

The swaged ends of actuating rods can now be

(*Concluded on page* 582)

CZECHOSLOVAKIA

Measurement of Inductance and Electromagnetic Energy in the Primary Circuit of an Ignition Coil

By I. KONECNY and V. RAKUSAN. (From *Elektrotechnicky Obzor*, Vol. 44, No. 7, 1955, pp. 375-380, 4 illustrations.)

THE design of ignition coils is determined by the electromagnetic energy W in the primary circuit required at the instant of interruption of the primary current. This energy is given by the expression

$$W = Li_p^2/2 \quad \ldots \quad \ldots \quad (1)$$

where L is the coil inductance and i_p the current at the moment of interruption. The measurement of inductance L for coils with an iron core is not a straightforward operation, inasmuch as this inductance varies with the degree of core saturation and depends on previous magnetizations. Direct impedance, or bridge, methods of measurement are unsuitable. To prevent the influence of previous magnetizations, a method has been developed for the measurement of L, which, by simulating working conditions, gives the values likely to be encountered in operation. The measurement is carried out with interrupted direct current of the same magnitude as that used in actual operation, the method being based on the following considerations.

The inductance L can also be determined by means of oscillograms of the transient current flowing in the coil when it is connected to a battery (B), as shown in Fig. 1, where (V) is a voltmeter, (R) is a rheostat, (O) is an oscillograph, (L) is the coil, (C) is a condenser, and (S) is a contact-breaker. The equation of this current is

$$V = Ri + \mathrm{d}\Phi/\mathrm{d}t \quad \ldots \quad \ldots \quad (2)$$

where V is the no-load voltage of the battery, i the current, R the total circuit resistance, Φ the magnetic flux, and t the time. The flux is given by the relation

$$\Phi = Li \quad \ldots \quad \ldots \quad (3)$$

As the inductance L is itself a function of the current,

$$\frac{\mathrm{d}\Phi}{\mathrm{d}t} = \left(L + i\,\frac{\partial L}{\partial i}\right)\frac{\mathrm{d}i}{\mathrm{d}t} \quad \ldots \quad \ldots \quad (4)$$

It is assumed in the following that L is either constant or changes very little, so that L is very much larger than $i(\partial L/\partial i)$. Hence, eq. (2) can be written

$$V = Ri + L\,\frac{\mathrm{d}i}{\mathrm{d}t} \quad \ldots \quad \ldots \quad (5)$$

and its solution for the case in which the coil is connected to the battery is

$$i = I_0(1 - \mathrm{e}^{-Rt/L}) \quad \ldots \quad \ldots \quad (6)$$

in which $I_0 = V/R$ is the steady-state current.

Eq. (6), or preferably eq. (5), could be used to calculate the magnitude of L from the oscillograms of the transient current. This method, however, is not suitable because, with oscillograms, large errors can occur in the determination of the tangent to the curve

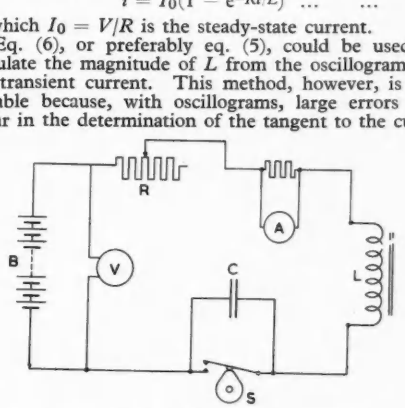

Fig. 1. **Test circuit used for determining inductance.**

di/dt. Furthermore, the method suffers from the fact that the initial magnetization of the core may not correspond with that occurring during operation.

Measurement with interrupted direct current obviates these disadvantages. Tests start with the determination of the time interval T_1, during which the contacts are closed. For this purpose, a moving-coil voltmeter is connected in series with the battery and the contact-breaker, which interrupts once every revolution. If the voltage with closed contacts is V, the voltmeter reading V' will be smaller when the contact-breaker rotates. If the contact-breaker rotates at n rpm and T is the time of one revolution,

$$T_1/T = V'/V = \lambda \quad \ldots \quad \ldots \quad (7)$$

and

$$T_1 = 60\lambda/n \text{ [sec]} \quad \ldots \quad \ldots \quad (8)$$

thereby permitting the determination of T_1 and the relative contact duration λ.

Determination of L can next be carried out with the aid of the circuit in Fig. 1 ; however, in this case, the oscillograph (O) is replaced by a moving-coil ammeter, and the contact-breaker (S) is rotated at n rpm. The rheostat (R) is adjusted so that the coil current and temperature are the same as those occurring in actual operation. Then, the current i_s and the battery voltage V_1 are observed, after which the circuit-breaker is stopped with its contacts closed and the steady-state current I_0 and voltage V_0 are measured. Finally, the contacts are separated and the no-load voltage V of the battery determined. These measurements complete the tests.

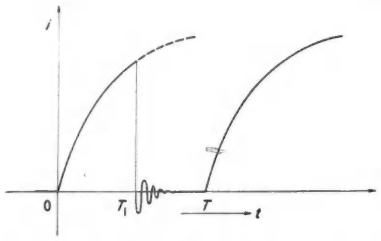

Fig. 2. **Transient current plotted as a function of time.**

In the case of a large battery, the internal resistance of which can be neglected, $R = V/I_0 \simeq V_0/I_0$. For the determination of the inductance, the transient current is again considered. This is plotted in Fig. 2 as a function of time t. In the interval when the contacts are closed, for $0 < t < T_1$, the current i is, for practical purposes, given by eq. (6), and the charge Q flowing through the coil is

$$Q = \int_0^{T_1} I_0 (1 - e^{-Rt/L})dt$$

$$= I_0 \left[T_1 - \frac{L}{R}(1 - e^{-RT_1/L}) \right] \quad \ldots \quad (9)$$

In the interval when the contacts are open, $T_1 < t < T$, oscillations occur because of the condenser. With suitable circuit components, the charge flowing through the ammeter in this interval is small and can be neglected. The current i_s which would be indicated on the ammeter is then obtained by dividing Q by T, or

$$i_s = I_0 \left[\frac{T_1}{T} - \frac{L}{RT}(1 - e^{-RT_1/L}) \right] \quad \ldots \quad (10)$$

This equation can be transformed, to simplify the calculation of L. Introducing the variable

$$x = RT_1/L \quad \ldots \quad \ldots \quad (11)$$

then, from eqs. (7) and (10),

$$\frac{i_s}{I_0} = \lambda - \frac{\lambda}{x}(1 - e^{-x}) \quad \ldots \quad \ldots \quad (12)$$

or

$$x\left(1 - \frac{i_s}{I_0\lambda}\right) = 1 - e^{-x}$$

Introducing $\alpha = 1 - \frac{i_s}{I_0\lambda}$ $\quad \ldots \quad \ldots \quad \ldots \quad (13)$

a practical equation for the calculation of x is obtained, as follows :—

$$e^{-x} + \alpha x - 1 = 0 \quad \ldots \quad \ldots \quad (14)$$

An approximate solution of this equation can be obtained numerically, or by the construction of the corresponding graph. The inductance L is then calculated from eq. (11).

Thus, determination of L is simple, its accuracy depending on the values of R and T_1. The calculated value of L includes, of course, the small inductance of the ammeter, a value which is generally not known. However, the error introduced by neglecting this value is counteracted by the error arising from neglecting the internal resistance of the battery, as previously mentioned.

This test method has been found satisfactory for conventional ignition coils with open iron cores, as variations in the speed of rotation of the contact-breaker, and in the values of i_s and I_0 do not result in variations in the value of the inductance L. This is not the case, however, with ignition coils on closed iron cores, as operation extends into the non-linear range of the magnetization curve, where L is no longer much greater than $i(\partial L/\partial i)$. It is believed that, in such cases, a modification of the test described might help, in which the contact-breaker is shunted by a resistance R_1. The current variations would then be limited to values not very different from i_p and the inductance thus obtained should correspond with working conditions. Inductance of coreless coils can also be measured satisfactorily by means of this method, provided that the resistance is sufficiently large to damp oscillations during open-contact periods.

The current i_p at the instant of contact-breaking is, according to eq. (6),

$$i_p = I_0 (1 - e^{-RT_1/L}) \quad \ldots \quad \ldots \quad (15)$$

and the electromagnetic energy, from eqs. (1) and (15), is

$$W = \tfrac{1}{2} L [I_0 (1 - e^{-x})]^2 \quad \ldots \quad \ldots \quad (16)$$

or, with eq. (14),

$$W = \tfrac{1}{2} L I_0^2 x^2 \alpha^2 \quad \ldots \quad \ldots \quad (17)$$

This equation, therefore, is a simple relation for the determination of W.

The inductance of the coil L, for which, with a given battery voltage V, circuit resistance R, and contact interval T_1, the energy is a maximum W_{max}, is obtained as follows :—

Substituting for L from eq. (11) into eq. (16), the energy W is expressed as a function of x only, so that

$$W = \tfrac{1}{2} I_0^2 RT_1 (1 - e^{-x})^2/x \quad \ldots \quad (18)$$

W is a maximum when

$$2x e^{-x} - 1 + e^{-x} = 0$$

or approximately $x = 1{\cdot}25638$.

The inductance L for W_{max} is, from eq. (11),

$$L = (RT_1)/1{\cdot}25638 \quad \ldots \quad \ldots \quad (19)$$

and the corresponding time-constant

$$\tau = L/R = T_1/1{\cdot}25638 \quad \ldots \quad \ldots \quad (20)$$

T_1 is usually determined by external conditions, e.g., by the highest engine speed.

Substituting the value of x into eq. (15), the current at contact-breaking $i_p = 0{\cdot}71533\ I_0$, and the energy $W_{max} = 0{\cdot}25585\ LI_0^2$.

Hot-Rolled Gear Wheels

By A. D. Kuzmin, M. V. Vasilchikov, and M. V. Barbarich. (From *Vestnik Mashinostroyenya*, Vol. 35, No. 3, March 1955, pp. 53-56, 7 illustrations, and Vol. 35, No. 9, September 1955, pp. 41-44, 6 illustrations.)

As the result of work carried out in Russia, a production process for the hot-rolling of gears has been developed, and yields gears of a quality entirely satisfactory for engineering purposes. This process has now been in operation for three years for the manufacture of three sizes of gears previously produced on gear-cutting machinery.

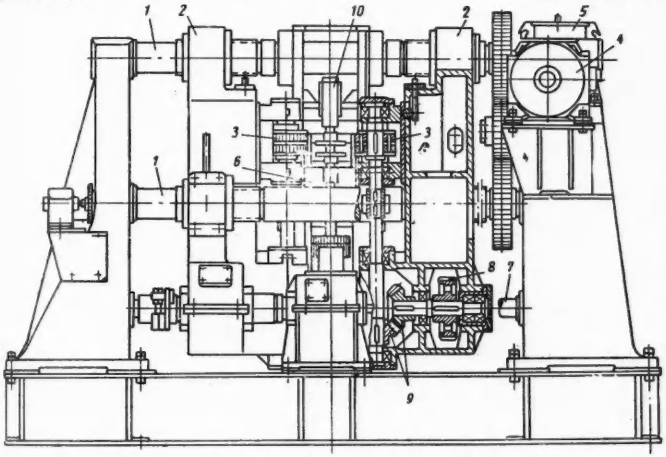

Fig. 1. **Longitudinal section through gear-rolling mill.**

The mill, illustrated in Figs. 1 and 2, is designed for the rolling of spur gears with diameters up to 220 mm and modules of up to 3mm. The basic components of the mill are the frame, the hydraulic power installation, and the main transmission with a two-stage spur reduction gear. The machine incorporates three lead-screws (1) (Fig. 1) of large diameter, with left- and right-hand threads, along which two carriages (2) move, carrying vertical rolls (3). These lead-screws are rotated by a separate motor (4), *via* a worm and spur-gear transmission (5). Depending on the direction of rotation of the lead-screws, the carriages can approach or withdraw from the work which is clamped, by means of the upper moving head (10), in a support (6), situated in the centre of the mill. The rolls are rotated by pinions sliding along the transmission shaft (7). These pinions, which are not shown in the drawing, mesh with gear wheels (8) driven by the bevel-gears (9). The transmission shaft (7) also drives the dividing mechanism through a pair of bevel gears (Fig. 2) and, in addition, is so designed as to permit angular adjustment of the rolls. The main driving motor of 18·5 hp is supplied by a motor-generator and ensures smooth control of the speed of the rolls in a range between 20 and 60 rpm, as well as their rapid reversal.

In the motor control equipment a device for the automatic reversal of the direction of the rotation of the rolls after a certain number of revolutions is included. By this means the formation of the correct tooth shape is ensured. The roll-feed mechanism is also supplied by the motor-generator and permits the control of the rate of feed in a range between 0·04 and 1·00 mm per half-revolution of the work. The feed mechanism includes a device for automatic disengagement after an advance of the rolls by a given amount. In addition, a dial indicator is built in for the accurate adjustment of roll position. The mill is provided with equipment for heating the banks *in situ* by high-frequency current.

Gear-rolling can be performed in two fundamentally different ways, one based on axial feed of the work (bar rolling), and the other on radial feed of the rolls (individual rolling). In the first case the blank, which is made up of a stack of separate blanks or a bar, is positioned between the centres of the support, the upper centre of which is integral with the dividing gear, which has the same number of teeth and the same module as the gear to be rolled. When rolling is initiated, the blank is so positioned that its top face is level with the annular heating coil disposed underneath the rolls. The dividing gear at this point meshes with the rolls and, when engaged, rotates the blank. As soon as the front end of the blank is heated to the rolling temperature, the feed mechanism is set in motion and the blank is advanced towards the rolls.

To facilitate gripping the blank, the infeed section of the working rolls is bevelled. In this section the main work of deformation of the blank is accomplished, and the tooth is formed, whilst the cylindrical portion of the rolls performs the calibration of the finished tooth.

The rate of feed of the blanks is so chosen that, in the time interval of its traverse through the heating coil, it is heated to the rolling temperature. After rolling, the blank is removed from the support when the latter is in its upper position, and, after removal, the support is returned to its lower position. The distance between the roll axes is adjusted before rolling to suit the diameter of the rolled

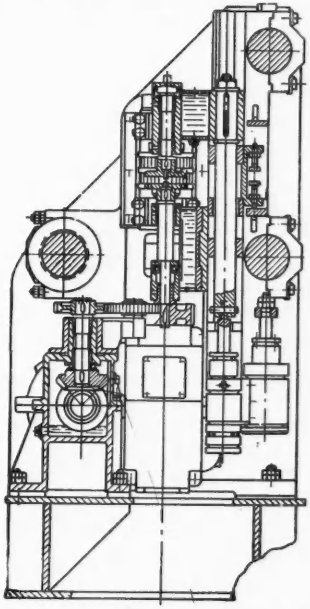

Fig. 2. **Transverse section through gear-rolling mill.**

gears and does not vary during rolling. The length of the bar-type blank is so chosen as to yield an even number of gears, taking the separation allowance into account. When rolling a stack of blanks, the need for this operation is eliminated.

In the individual rolling method the blank is placed on the lower fixed table of the support (6) (Fig. 1) and is clamped by means of the upper moving head (10). When the carriages approach each other, the rolls plastically deform the blank material and produce the gear teeth. These teeth roll in mesh with the teeth of the rolls and so receive a standard involute profile. The heating of the blanks in this process is performed by a segmental inductor situated between the rolls. Initially, the blank and rolls rotate, whilst the feed mechanism is disengaged until the blank is heated. When the required temperature is reached, the feed mechanism is engaged.

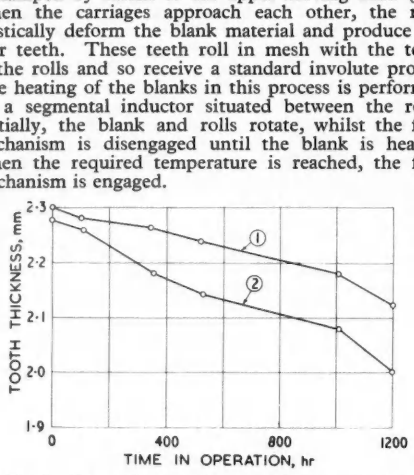

Fig. 3. **Wear of a rolled gear and of a cut gear.**

To change over from one method of rolling to the other, the working rolls and the moving support must be exchanged. The bar-type method can be used only for the rolling of straight and helical spur gears; the individual-blank method can be used to obtain gears of any type, including straight, helical, and herringbone.

The basic operations in the production of gears, for which the bar-type method of rolling has mainly been used, is as follows :—

Bar stock is cut into blanks on circular saws; the blanks are then hammered out to the required diameter on forging hammers and are turned into gear blanks on engine and capstan lathes. These blanks are hot-rolled into gears in the machine and are allowed to cool in sand. The centre hole and end faces are machined on engine and capstan lathes, and the keyway is produced in a broaching machine. Finally, the gears are heat-treated by high frequency.

The teeth of rolled gears are not normally machined. Their tooth flanks are usually covered with a thin layer of Fe_3O_4 and have a smooth surface resembling that of rolled sheet. To avoid excessive scale formation the heating temperature of the blank during rolling does not exceed 1050 to 1100° C at the beginning, and 850 to 950° C at the end of rolling.

When rolling gears with a module of 1·5 mm and a number of teeth between 48 and 68, the working rolls rotate at a speed of 30 rpm. The rate of feed of the blank into the rolls is between 6 and 8 mm/sec. As a result of the relatively good accuracy of the outside diameter of the gears ensured by rolling, the boring of the hole is carried out with reference to the tip diameter of the teeth.

After rolling, when the gear has cooled, the tooth crown is inspected for maximum diameter and tooth thickness. If these dimensions are within prescribed limits of accuracy, the gears are accepted for completion. It has been found that scrap is almost entirely confined to the starting-up period of the mill, and is produced only at certain intervals whilst the rolls, in spite of their intensive water cooling, are being heated up. At this point it is necessary to increase the centre distance between the rolls. In continuous work a state of equilibrium is reached when no further adjustments are required.

Occasionally, more thorough inspection of the meshing characteristics of the rolled gear is carried out. The result of a laboratory check on a particular gear of 33 teeth and a module of 1·5 mm is a maximum radial error of 0·1 mm and a maximum accumulated pitch error of 0·09 mm. It is claimed that the test-bed performance of an electric rock drill which incorporates such rolled gears has proved their noise level to be lower than that of cut gears.

The diameter of the blank before rolling includes an allowance determined by practice. This allowance is added to the theoretical diameter, which is smaller by 0·14 module than the outside diameter of the finished gear. The need for the extra allowance arises from the flow of metal in the axial direction, and its value depends on the gear dimensions and the method of rolling. For example, in gears of 1·5 mm module and a width of 25 mm, the allowance is 0·66 module for gears with a number of teeth between 40 and 68, but drops to 0·52 module in gears with 24 teeth.

The rolls are, in effect, gears of the same module as the rolled gears and are cut on ordinary gear-cutting machines and case-hardened. A roll so made can be used for rolling between 3000 and 5000 gears, whilst it is reported that a gear hob can be used for a maximum of 900 gears of the same type. In rolling it has been found that any pitch errors in the rolls are averaged out in the rolled gears, the pitch errors of which are therefore smaller.

The intensive plastic deformation during the shaping of the teeth helps to attain a more favourable grain flow in the tooth material than can be obtained with machined gears. Moreover, the material is compressed to a depth of 0·5 mm over the entire tooth surface, thus improving wear resistance, as shown in Fig. 3, in which curve (1) represents the rolled gear and curve (2) the cut gear.

The hourly productivity of this mill has reached 200 gears of 1·5 mm and 23 teeth and 167 gears of 42 teeth, with a 1-5-mm module. However, its output is limited by the heating of the blanks and could be increased if a more powerful high-frequency induction-heating installation were used. The development programme for this particular mill aims at the widening of the size range of the rolled gears up to a module of 6 mm and a diameter of 370 mm. Another mill, designed to produce gears of a module up to 10 mm and a diameter up to 600 mm, is under test.

Fatigue Tests on Hot-Rolled Gears

In order to establish the fatigue properties of hot-rolled gears, tests were carried out in a rig consisting of a single-stage reduction gear driving a prony brake. Both gear and pinion, of 0·43% carbon steel, with 30 and 70 teeth respectively and a module of 2 mm, were rolled by the axial-feed method. Comparative tests were carried out with cut gears and with rolled gears without heat treatment after cooling in air following the rolling operation. The rolled gears were finish-cut by the removal of 0·15 mm from the tooth surface, to

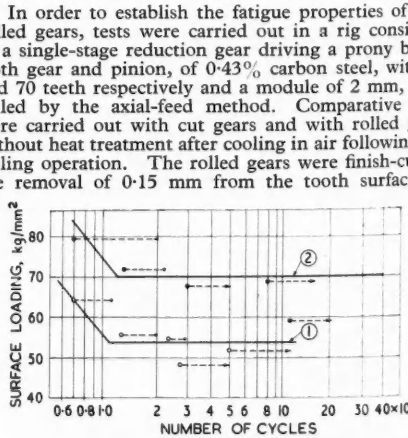

Fig. 4. **Endurance of a cut gear and of a hot-rolled and finish-cut gear.**

obtain the same accuracy as that of the cut gears. After this finishing operation the surface roughness of the rolled gears was reduced to 8 microns. In order to obtain the same surface roughness the cut gears were lapped-in before testing. The Brinell hardness of the rolled gears was 200 to 220. The cut gears were normalized to obtain the same degree of hardness.

Fatigue failure of the gears was judged by progressive pitting, casual pitting without progressive deterioration being disregarded. The load was plotted against the number of cycles corresponding to the initiation of progressive pitting, as shown in Fig. 4, in which curve (1) represents the cut gear and curve (2) the hot-rolled and finish-cut gear. The load is plotted as a surface pressure obtained from the total tooth pressure by means of the Hertz formula.

Microscopic examination of the polished and etched toothed surfaces after the initiation of fatigue failure showed some difference in the nature of the pitting. In the cut gears the craters were small but deep, whereas in the rolled gears the craters were larger but shallow.

Hot-rolled gears with the as-rolled surface were also tested in the same rig, since such gears are already used in practice. The results are plotted in Fig. 5 and show that, in spite of the reduced accuracy of the gears, leading to additional dynamic loads, and in spite of the well-known deterioration of the fatigue properties in a hot-rolled surface, the gears nevertheless have a useful endurance strength of just over 40 kg/mm², compared with 53 kg/mm² for the cut gears and 70 kg/mm² for the rolled and finish-cut gears.

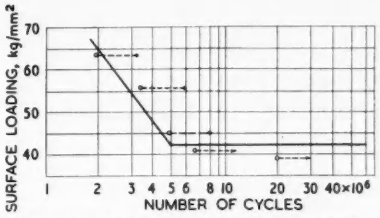

Fig. 5. **Endurance of a hot-rolled gear with as-rolled surface.**

U. S. A.

The Effects of Heat Treatment on the Mechanical Properties of 6Al-4V Titanium Alloy

By R. G. SHERMAN and H. D. KESSLER. (From *Steel*, Vol. 137, No. 11, September 12, 1955, pp. 98-100, 4 illustrations.)

WHILE many commercial alpha-beta alloys offer heat treatability and excellent tensile properties, their use is generally limited to temperatures below 600° F. However, an alpha-beta titanium alloy, Ti-6Al-4V, available for little more than a year, has rapidly gained in importance, inasmuch as it has high strength, good ductility, and excellent elevated-temperature strength and stability up to 1000° F.

To obtain moderately high strength levels with Ti-6Al-4V in sections under 1¼ in. thick, heat treatments somewhat similar to those for aluminium must be used.

In solution treatment, titanium alloys are heated in a two-phase alpha-beta field, and are rapidly cooled to room temperature. Subsequent hardening on ageing results from the partial decomposition of the beta phase and the precipitation of alpha (both of these phases being terminal solid solutions).

Upon quenching from high in the alpha-beta field, a supersaturated beta solid solution results. This beta is unstable on reheating at low temperatures but will not decompose at room temperature. If heated for long periods at 600 to 900° F, the metal will age but low ductility will result. Generally, ageing temperatures between 900 and 1200° F from 2 to 24 hr give the best combination of properties.

Solution treatments are carried out in the alpha-beta rather than in the beta field for two main reasons, i.e., (1) when the beta transus (beta/alpha plus beta transition temperature) of about 1825° F is approached, ductilities drop off to low values and grain growth proceeds at a high rate; and (2) the leaner beta formed near the

Fig. 1. **Photomicrograph of Ti-6Al-4V after 1750° F (1-hr) solution heat treatment and water quench.** (×575)

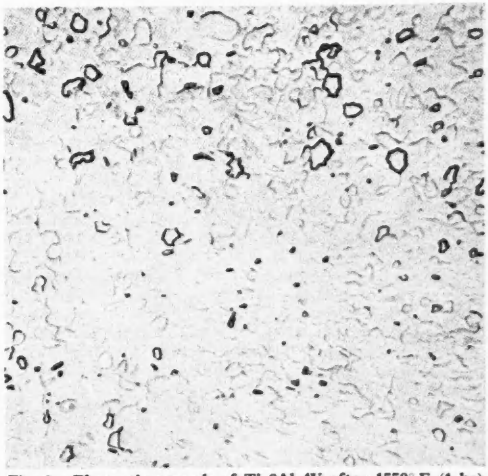

Fig. 2. **Photomicrograph of Ti-6Al-4V after 1550° F (1-hr) solution heat treatment and water quench.** (×575)

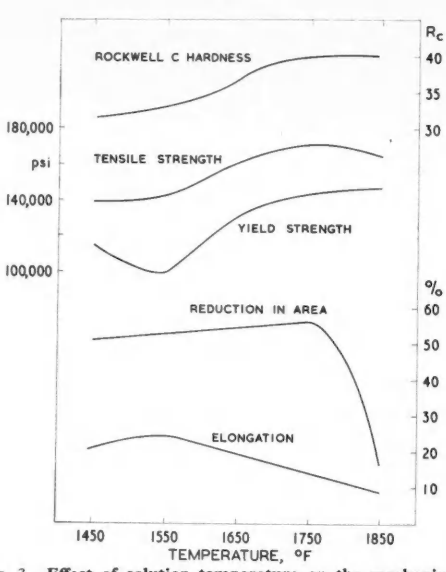

Fig. 3. **Effect of solution temperature on the mechanical properties of Ti-6Al-4V.**

transus temperature is extremely unstable and ages during the quench, even in small sections.

Despite this ageing, excellent combinations of strength and ductility are available at temperatures up to 1750° F. At higher temperatures, ductility drops off and the basic advantages of solution treatment are lost.

The same principles apply to the selection of forging temperatures. Temperatures no higher than 1750° F should be used in finish-forging, although 1900° F or higher is used in forging ingots and heavy billets. Because these high temperatures do not give optimum properties, lower temperature working, combined with heavy reductions, is subsequently used to restore good ductility.

The lower limit of forging temperature is strictly an economic consideration of the rate at which the metal can be formed. Temperatures down to 1400° F have been used to advantage where sufficient power was available to deform the metal, which is stiff at this temperature.

The 1750° F (1-hr) water-quench treatment results in the best combination of as-quenched properties, giving a small amount of primary alpha in a transformed beta matrix (Fig. 1). Yield, tensile, and fracture strengths and ductility are at a peak (Fig. 3).

The 1550° F (1-hr) water-quench treatment, giving fine-grained alpha, plus retained beta structure (Fig. 2), produces a minimum yield-tensile ratio of 0·7, i.e., the yield strength drops to about 100,000 psi, while the tensile strength is above 140,000 psi (Fig. 3). The reason for this minimum is not known, but it is fairly certain that the composition of the beta is the governing factor.

The low-yield-strength, soft material offers the advantages of good machinability and excellent cold formability. Following machining or forming, it can be aged to a higher strength by the proper combination of temperature and time. It should not be used at elevated temperatures as solution-treated, because in this condition it is unstable.

Response to ageing is rapid at 900° F, following the 1550° F (1-hr) water-quench treatment. Peak strength is reached in 30 min or less. For longer times, the strength remains essentially constant.

The rate of quenching from the solution temperature is important in developing good tensile properties. A fast quench is necessary for maximum retention of beta for subsequent ageing.

In small sections, an extremely fast quench in a sodium hydroxide solution or a somewhat slower quench in water shows considerable advantages in strength (after ageing) over air cooling. (During the air-cooling cycle, decomposition of the beta phase renders the alloy less heat-treatable.) In heavy sections, the sodium hydroxide quench offers no strength advantages over water quenching. Little, if any, age-hardening can be obtained after furnace cooling from the solution-treating temperatures.

Duplex heat treatment produces higher strengths for section thicknesses up to 1½ in. Beyond this amount, it has no advantage over the straight anneal.

Core strength varies inversely with the section. To obtain a desired strength level, section size must be considered before selecting the heat treatment. The 1550° F treatment should produce greater depth of hardening or ageing than the 1750° F treatment, because the richer beta existing at the lower temperature is more stable.

One main advantage of Ti-6A1-4V is its stability under stress at elevated temperatures. For example, compressor-blade specimens stressed to 50,000 psi at 800° F for 1000 hr and then tensile-tested show no embrittlement. The test sometimes results in an increase in tensile strength, with little or no loss in ductility. Deformations resulting from the test conditions correlate with tensile strength, indicating that heat treatment has an effect upon short-time creep.

Although duplex heat treatment offers better elevated-temperature strength without embrittlement, the ageing temperature should be higher than the service temperature. Ageing should be of the order of 24 hr for greatest stability.

Temperatures below 900° F should be avoided, because service at temperatures as low as 600° F could cause further ageing and possible embrittlement. Ageing treatments of 900 to 1000° F for 24 hr, following either a 1550° F (1-hr) water quench, or 1750° F (1-hr) water quench, offer sufficient stability to render excellent service without danger of embrittlement up to 800° F.

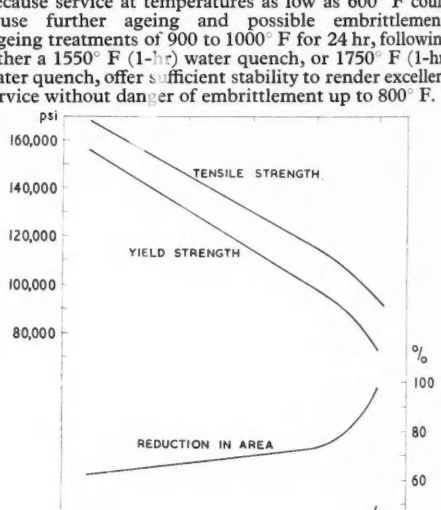

Fig. 4. **Elevated-temperature properties of Ti-6Al-4V.**

The elevated-temperature properties of Ti-6A1-4V, based on a 1750° F (1-hr) water-quench treatment, with ageing for 24 hr at 1000° F, are shown in Fig. 4.

The State of Research on Steam Properties

By L. Hrdlicka. (From *Strojirenstvi*, No. 8, 1955, pp. 630-632, 4 illustrations.)

Considerable effort is being made to increase knowledge of the properties of steam. The last international conference for the compilation of steam tables took place in the U.S.A. in 1934, and the resulting tables contained, among others, enthalpy values of superheated steam up to 550° C and pressures of 300 atm abs., and specific heat values of superheated steam up to 450° C and 200 atm abs.

Characteristic steam data, however, are now needed for much higher temperatures and pressures than those found in these tables. More reliable viscosity and thermal conductivity values for steam are necessary, together with a more accurate correlation between the international and the thermodynamic temperature scale (based, for instance, on the boiling point of sulphur and the melting point of silver).

The most important contributions to the determination of steam properties since 1934 have been as follows :—

(1) Development of the method for measuring enthalpy variations with pressure at constant temperature, and determining enthalpy values in the range between 40 and 125° C (Collins and Keyes, 1938).

(2) Investigation of the infra-red spectrum of water vapour for the determination of specific heat values (National Bureau of Standards, Report No. 3103).

(3) Very accurate measurement of the heat of evaporation in the range between 0 and 100° C (Osborne, Stimson, and Ginnings, 1939).

(4) p-v-T relations for water at high pressures and temperatures (Kennedy, 1950).

(5) Direct measurement of p-v-T relations in the range between 431 and 600° C, and up to 524 atm abs. (Kirillin and Rumjancev, 1950).

(6) Investigations into the specific heat of superheated steam at constant pressure up to 300 atm abs. and 550° C (Timrot and Vargaftik, 1940).

The results of this experimental work and of theoretical investigations are contained in the tables of Vukalovic (1951) and in those of the Thermotechnical Institute of the U.S.S.R. (1952). Juza, of Czechoslovakia, calculated values for the entropy diagram of steam up to 400 atm abs. and 750° C.

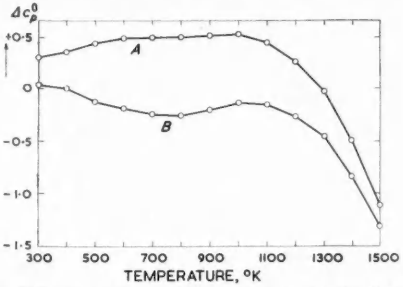

Fig. 1. **Differences in specific heat values $c_p°$ [kcal/kg °C] of water vapour as a function of temperature.**

$$\text{Curve A}: \quad \Delta c_p° = \frac{(c_p°)_{NBS} - (c_p°)_{USA}}{(c_p°)_{NBS}} \times 100$$

$$\text{Curve B}: \quad \Delta c_p° = \frac{(c_p°)_{NBS} - (c_p°)_{USSR}}{(c_p°)_{NBS}} \times 100$$

Fig. 1 shows the differences in the specific heat values of water vapour as a function of temperature, in accordance with the tables of Vukalovic and those of Keenan and Keyes (N.B.S. Report No. 3101). Fig. 2 shows differences in the enthalpy values in use in Czechoslovakia, the U.S.S.R., and the U.S.A. at pressures of 100, 200, and 300 atm abs.

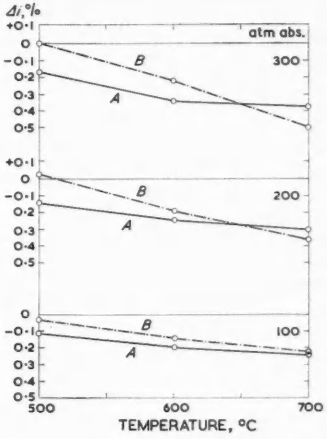

Fig. 2. **Differences in enthalpy values i [kcal/kg] in Czechoslovakia, the U.S.S.R., and U.S.A., at different pressures.**

$$\text{Curve A}: \quad \Delta i = \frac{(i)_{CZECH} - (i)_{USSR}}{(i)_{CZECH}} \times 100$$

$$\text{Curve B}: \quad \Delta i = \frac{(i)_{USA} - (i)_{USSR}}{(i)_{USA}} \times 100$$

These differences point to some of the work confronting the next international conference. Tables up to 800° C and 1000 atm abs. are proposed, and not only enthalpy values and p-v-T relations, but also viscosity

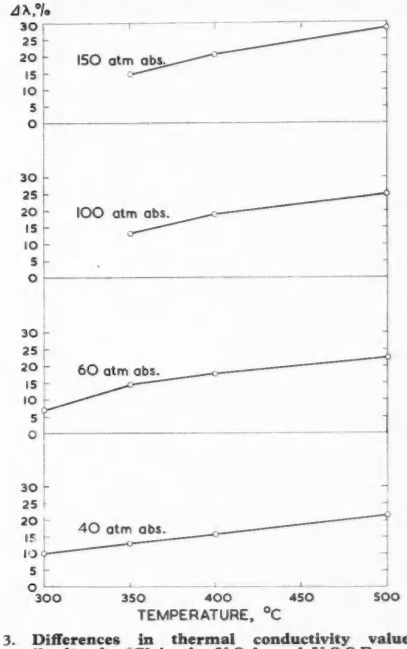

Fig. 3. **Differences in thermal conductivity values λ [kcal/m hr °C] in the U.S.A. and U.S.S.R.**

$$\Delta\lambda = \frac{(\lambda)_{USSR} - (\lambda)_{USA}}{(\lambda)_{USSR}} \times 100$$

and thermal conductivity values of steam, are required.

Large variations exist in viscosity and thermal conductivity values, as measured by different workers. Viscosity determinations with the aid of capillary tubes are not sufficiently accurate, though Kestin hopes to obtain better results by Maxwell's method. Thermal conductivity has been measured by various methods. Timrot and Vargaftik used an electrically heated platinum wire, which was built into a tube containing the vapour. In the method of Keyes and Sandell (1950), the source of heat and the thermocouples are separated from the measuring instrument proper. Their conductivity values are up to 30% lower than those of Timrot and Vargaftik (Fig. 3).

Reliable thermal conductivity values are especially important in the case of steam superheaters for estimation of their tube-wall temperatures, which may reach magnitudes of the order of 600° C, in which case errors in temperature estimates of 10° C would mean a 10% variation in the tensile strength of the tube, sufficiently illustrating the need for accurate thermal conductivity data.

U. S. A.

The Effects of Adding Copper to Iron Powder Compacts

By P. U. GUMMESON and L. FORSS. (From *Precision Metal Molding*, Vol. 13, No. 10, October 1955, pp. 55-57, 92, and No. 11, November 1955, pp. 44-45, 83-84, 15 illustrations.)

IT is well known that iron powder compacts assume quite different dimensional changes when additives, especially copper, are introduced. For most iron powders the ultimate dimensions are larger when they are mixed with copper powder, as compared with the plain iron part. This phenomenon is usually referred to as copper growth. It should be mentioned that some powders do not show this property, while others may even show a copper shrinkage. Although most commercial iron powders behave in different ways, there is, however, a definite relationship between them.

A simple comparison in graphical form is shown in Fig. 1 between three different commercial-grade reduced iron powders *A*, *B*, and *C*, and demonstrates the effect of sintering temperature on dimensional changes when 7½% copper is added. The test specimens were rectangular bars, 1·25 × 0·5 × 0·25 in. The copper powder was of the reduced type with a maximum 100-mesh particle size. Sintering time was 45 min at heat under a hydrogen atmosphere. Dimensions were calculated from tool size. Unless otherwise stated, all the tests described in this paper were also made under these conditions.

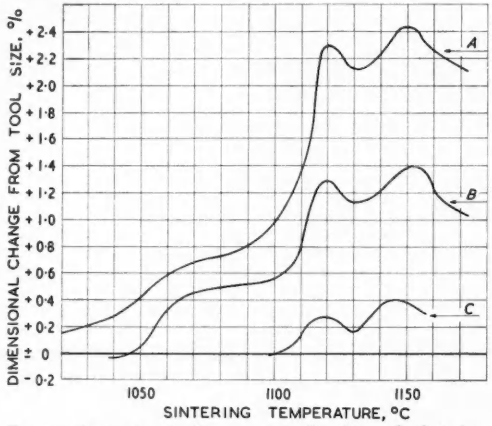

Fig. 1. **Dimensional change as a function of sintering temperature for three different iron powders.**
Test specimens: 7½% copper, 1% zinc stearate.
Sintered density: 6·2 gm/cm³.
Sintering time: 45 min at heat.

In the most frequently used temperature ranges, the so-called copper growth ranges between 0 and 2½%, or 0 to 0·025 inches/inch. Of special interest are the typical two maxima surrounding a minimum, a phenomenon which was found to be more or less characteristic of all the various iron powders investigated, not only those of the reduced type. It is interesting, not only because it is difficult to explain, but also because it has an influence on production problems, to consider the fact that dimensional control will be so closely linked to rigorous temperature control. If, for example, sintering is effected between 1125 and 1150° C, the dimensions of the part will be influenced by temperature variations much more than if the minimum were not present.

A series of tests was run with iron powder *B* to illustrate the influence of both copper content and sintering temperature on dimensions, strength, and hardness. Parts with two different densities were included in the tests. Among other interesting results, it was found that a certain strength or hardness can be obtained under widely different conditions. The influence of sintering temperature on strength and hardness is generally less than on dimensions, while increases in copper content increase strength only when the solubility limit of copper in gamma-iron is not reached.

From these investigations an outline of the influence on dimensional changes of some of the most important variables is as follows :—

(1) *Sintered density* :—Sintered density has a rather modest influence on dimensional change, especially at higher copper contents and higher sintering temperatures. Generally speaking, somewhat increasing dimensions with increasing density can be expected.

(2) *Sintering time* :—Test specimens from iron *B* with 7½% copper and 1% zinc stearate were pressed to a density of 6·2 gm/cm³. Fig. 2 shows that only very short sintering times (below 10 min of heat) have a great influence on copper growth. Prolonged sintering times mean somewhat smaller dimensions. In this test, the time to reach temperature was less than two minutes.

(3) *Heating rate* :—The time taken for specimens to reach sintering temperature has an influence on ultimate dimensions. Test specimens from iron *B* with 7½% copper and 1% zinc stearate were pressed to a density of 6·2 gm/cm³. The specimens were put into the furnace, which was held at different starting temperatures, after which the furnace temperature was raised to 1125° C and held there, so that the total time for the specimen in the furnace was the same in all tests.

A slowly heated specimen will develop smaller dimensions than one which is heated rapidly to sintering temperature; in other words, a lower heating rate causes more shrinkage and smaller final dimensions. It is believed that this has to do with the time the specimen is held in a temperature range around the melting point of copper.

(4) *Cooling rate* :—The cooling rate, no doubt, is of importance for the properties of the part, but is not

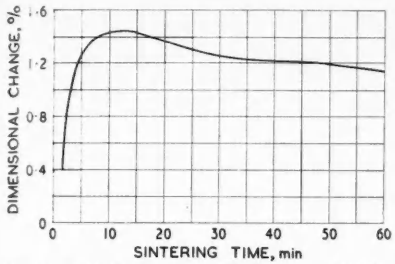

Fig. 2. **Characteristic relationship between sintering time and dimensional change for an iron-copper mixture.**
Test specimens: Iron powder, with 7½% copper and 1% zinc stearate.
Sintered density: 6·2 gm/cm³.
Sintering temperature: 1125° C.

considered in this paper, as it is more closely related to the heat-treating properties of iron-copper alloys. The cooling time in all investigations presented was about 15 min, unless otherwise stated.

(5) *Screen size of the powders* :—Generally speaking, the finer the mesh size of the powders, the smaller will be the dimensions of the part after sintering. This phenomenon seems to apply not only to iron-copper mixtures, but to other powder combinations as well.[1]

(6) *Other additives* :—The addition of a third component to iron-copper mixtures will have a more or less radical influence on the ultimate dimensions. Although the mechanism of copper growth has not as yet been discussed, it should be mentioned that copper growth can be expected to be influenced by additions which change the amount or duration of the liquid phase by (*a*) changing copper solubility in iron; (*b*) changing iron solubility in copper; and (*c*) changing the surface tension of the molten copper phase, etc.

Decreasing copper solubility in iron is accomplished with perhaps the most common additive, carbon (graphite), which decreases the copper growth of all iron powders, especially those which normally show a high copper growth. Carburizing sintering atmospheres should have the same influence, although this has not been studied.

Small additions of tungsten oxide will considerably decrease copper growth for all irons, particularly for irons with high normal copper growth. This is shown for irons *A*, *B*, and *C* in Fig. 3. The mechanism in this case is not fully understood.

Ferrophosphorus additions will increase the amount of liquid phase and thereby decrease copper growth.

Causes of Growth and Shrinkage

To obtain a closer view of the mechanism of copper growth, it is necessary to discuss separately the factors causing growth and those causing shrinkage, the algebraic sum of which is equal to the so-called copper growth.

Growth :—

It seems reasonable to assume that growth factors are equal for all pure iron powders and that they can be determined from the iron-copper constitutional diagram and the lattice structure of the alloy.

When a certain amount of copper is completely dissolved in the iron, it can be expected that the increase in volume of iron is approximately equal to the volume of the dissolved copper, plus a growth which originates in the expansion of the iron lattice when copper atoms are substituting iron atoms at temperatures above the alpha-gamma transformation point and remain in the lattice after cooling. There is metallographic evidence that, at the cooling rates encountered in normal sintering practice, little, if any, copper will precipitate.

Taking into consideration that the maximum solubility of copper in iron at the temperatures involved is in the region of 8 to 9%, these idealized growth factors can be estimated to a maximum of 3 to 3·5% linear expansion. It is obvious that this growth of volume cannot fully be offset by the pores in the compact or the pores left by the copper particles.

Shrinkage :—

It follows from the above that the explanation of the different copper-growth properties among different iron powders is most likely to be found in the factors causing shrinkage during sintering. These consistently present shrinkage factors are superimposed on the growth factors and therefore decide the final dimensions.

Since so many variables influence these shrinkage factors, it seems logical to conclude that process variables should be chosen to give maximum dimensions, if close tolerances are desired, and this is in accordance with the authors' experience.

To determine at what stage in the sintering cycle growth and shrinkage factors respectively become important, dilatometric tests were carried out on the three reduced iron powders *A*, *B*, and *C*, with and without a 7½% addition of copper powder.

The behaviour of the three powders was found to be very similar up to approximately 900° C, or up to the point of transformation of alpha-iron to gamma-iron, resulting in the shrinkage of the specimens between 900 and 1000° C.

Above 1000° C all three specimens start to grow to a greater degree than can be explained by thermal expansion. The difference between the three powders is substantial. During the cooling period there was noticed, in addition to the thermal contraction, the transformation of gamma-iron to alpha-iron at a lower than normal temperature for iron, the explanation for which is to be found in the dissolved copper.

If the curves of dimensional changes during sintering without copper are subtracted from those of dimensional changes during sintering with copper, the resulting curves should serve to picture the net result of copper additions to the powders, by eliminating all changes due to thermal expansion and contraction, escaping gases,

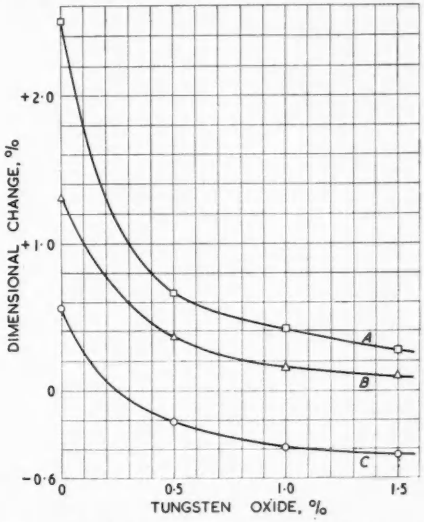

Fig. 3. **Effect of small additions of WO_3 on the dimensional changes of iron-copper mixtures.**
Test specimens: Iron powder, with 7½% copper and 1% zinc stearate.
Sintered density: 6·2 gm/cm³.
Sintering temperature: 1125° C.
Sintering time: 45 min at heat.

transformations, etc., as well as dimensional changes in straight iron. From the curves resulting from these dilatometric tests, always bearing in mind the limitations of the test equipment, the following conclusions would appear to be justified :—

(1) Copper growth does not start until at, or slightly below, the melting point of copper.

(2) The growth continues for some time after the specimens have reached the sintering temperature.

(3) The growth is offset to some extent by a shrinkage, the magnitude of which depends on some property of the iron powders.

It has been previously assumed that the growth should be equal for all pure iron powders and should be of the order of approximately 3% linear expansion. To explain the shrinkage, it is necessary to discuss the mechanism of sintering, a subject which has been well covered in the literature.[2,3,4,5]

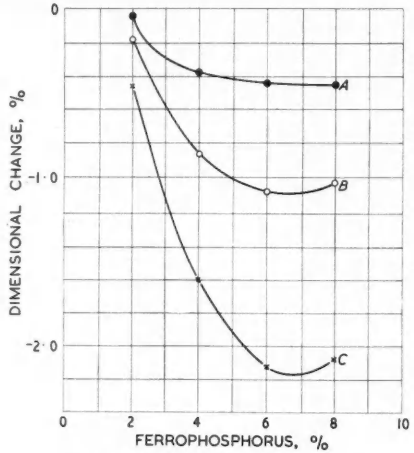

Fig. 4. Liquid-phase sintering.
Test specimens : Iron powder, with ferrophosphorus.
Sintered density : 6·2 gm/cm³.
Sintering temperature : 1125° C.
Sintering time : 45 min at heat.

If the net copper content of an iron part is 7 to 8%, the result of sintering under normal conditions must be complete dissolution of the copper into the iron. Diffusion of copper atoms into the iron should result in expansion of the iron skeleton. However, if the copper phase is liquid, there will be a rapid saturation of this liquid phase with iron, followed by an exchange of atoms between the iron-rich and copper-rich phases, resulting in dissolution of iron atoms from areas with high curvature, and reprecipitation of an iron-rich phase on areas with low curvature. This process is known as densification.

It seems reasonable to believe that the more irregularly shaped are the iron particles, the finer will be their pore structure, the greater will be the contact area with the liquid phase, and the faster will densification due to atom displacement proceed, offsetting the expansion due to the copper dissolving in the iron. This process of dissolution and reprecipitation is virtually confined to the interval of the liquid-phase existence. The speed with which the liquid phase is formed, as well as its duration, has a large influence on densification.

This influence of copper on the densification rate is also present to a lesser extent below the melting point of copper, although here there is sintering by solid-phase diffusion only. Cannon and Lenel[4] have studied these phenomena under somewhat different conditions and have explained the densification process as being composed of liquid flow, solution, and reprecipitation, and solid-phase sintering. Dawihl and Rix[5] discuss the solid-phase sintering as particle transformation and particle adaption, attributing the sintering properties to the production method and preliminary treatment of the powders.

It would appear that one of the main reasons for the different copper growth values of pure iron powders is to be found in differences in their pore structure, specific surface, and particle shape. The finer the pore structure, the larger the specific surface, and the more irregular the particle shape of the iron powder, the more will the densification rate during sintering be accelerated by the presence of a second phase which is liquid, or at least near its melting point. A number of observations supports this statement.

The three iron powders *A*, *B*, and *C* have widely different pore structures. Powder *A* has the coarsest pore structure and the largest copper growth, and powder *C* the finest pore structure and smallest copper growth, while powder *B* in both respects takes an intermediate position. Powder *A* has the smoothest, and powder *C* the most irregularly shaped, particles. Determinations indicate that the specific surface of powder *B* is of the order of 3 to 5 times that of powder *A*.

It could be expected that the dissimilarity in densification will appear with other liquid phases than copper, provided that they have a mutual solubility with the iron. Fig. 4 shows the dimensional changes obtained when iron powders *A*, *B*, and *C* are mixed and sintered with varying amounts of ferrophosphorus (20% P), which has a liquid-phase eutectic at 1050° C. The diagram may serve as an illustration of the shrinkage factor alone.

Further evidence will be found in the following experiences :—Prolonged heat treatment of an iron powder at higher temperatures leads to a decrease in specific surface, and an increase in the size of the individual pores, as well as disappearance of surface irregularities. Such heat treatment will increase the copper growth of iron powders. Densification of iron powders by severe milling likewise will increase its copper growth.

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Advances in Tube Swaging

(*Concluded from page* 573)

designed for thickened ends, and the overall weight of the rod is therefore reduced. Designers can call for a swaged tube to be completely closed, if necessary, the only consideration being that interstage anneals and more dies will be required where a reduction of more than 65% is desired. The designer can estimate a minimum of 70% retention of cross-sectional area for swaged tube ends up to 65% tube reduction.

The latest development on swage dies has been to conduct tests on a fluted die which has helical flutes extending only through the transition area. Preliminary results indicate that there is less radial grain distortion through the transition area and that severe swaging operations are easier to accomplish without buckling the tube.

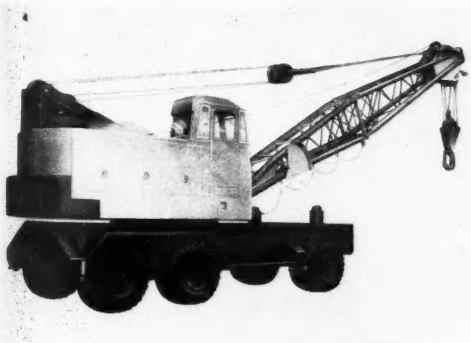
British Industrial Developments

Mobile Cranes

Incorporating several new features, and designed to lift a load of 25 tons at a 10-ft radius, are three additions to the Coles range of mobile cranes, built by Steels Engineering Products Ltd., of Sunderland.

These new cranes comprise respectively a self-propelled version (model S.2710), a lorry-mounted version (model L.2710), and a rail version (model R.2710). Much of the equipment is common to all three versions, the principal item being the Coles system of diesel-electric or petrol-electric transmission. This system incorporates separate electric motors for the crane motions of hoist, derrick, and slew, and on the rail and self-propelled cranes for travelling. A chassis-mounted diesel engine powers the lorry-mounted crane for travelling. Smooth and precise control of all crane motions is a feature of all models, while the simple layout of the grouped finger-tip controls in the operator's cab also ensures a minimum of operator fatigue. A 30-ft strut-jib of lattice construction is fitted to all versions, and this can be extended to a maximum of 80 ft. An optional item of equipment for all models is a 20-ft fly-jib.

The self-propelled model offers a choice of power units, i.e., a Ford petrol engine (64 hp at 2200 rpm) or a Perkins diesel engine (65 hp at 2200 rpm). The power unit drives a specially designed variable-voltage generator which in turn powers the hoist, derrick, and slew and travel motors. Automatic reversing mechanism on the steering gear is an important feature on this crane. The mechanism gives "correct" steering, irrespective of the position of the operator's cab in relation to the chassis and wheels of the crane. Foot-operated air brakes act on the four rear wheels of the crane, which also has a mechanical handbrake. Included among the optional equipment available is an audible and visual safe-load indicator; a single hook for faster hoisting of light loads; single or twin free-running hoist drums; power-assisted steering; and a heater or fan for the cab. Grabs or magnets can also be supplied for the crane.

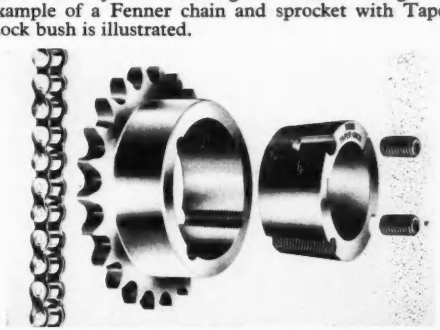


The lorry-mounted model is mounted on a Coles 6 × 4 crane-carrier chassis. An A.E.C. diesel engine is used for travelling and gives a maximum road speed of about 27 mph. Power-assisted steering is a standard feature, and air-pressure, foot-operated brakes are fitted on all wheels. A main gearbox has five forward speeds and one reverse, and an auxiliary gearbox is also fitted. A six-wheel-drive chassis can be supplied if the crane is to be used on undeveloped sites or for considerable cross-country work. On the crane itself there is a Perkins diesel engine (65 hp at 2200 rpm) driving the generator for powering the hoist, derrick, and slew motors. A full range of standard equipment is fitted, and optional items are also available. An important feature of this model is a removable tail-weight. Hydraulic equipment can be supplied to remove the weight without outside assistance.

The rail version offers the same choice of power units as the self-propelled crane. Mounted on eight single-flange, steel-tyred wheels the crane has air-pressure, foot-operated shoe brakes fitted to all wheels; a handbrake is also fitted. The crane has similar specifications to the self-propelled model and is fully equipped, but in the list of optional equipment are two important items, i.e., railway-type spring buffers and derailing beams.

Taper-Lock Bushes in Chain Sprockets

It is announced by J. H. Fenner & Co. Ltd., of Hull, that Taper-Lock bushes have been applied to a standard range of chain pinions and wheels, and that roller chain is also available. Chain drives for most industrial applications are thus now ready for use, without the need for any re-machining or skilled fitting. An example of a Fenner chain and sprocket with Taper-Lock bush is illustrated.



These Taper-Lock bushes are all absolutely interchangeable, not only in chain sprockets, but also in V-pulleys and flexible couplings, while the range of bores makes changing from one size of shaft to another equally easy and rapid. Safety is assured because these bushes mount flush and grip like a shrunk-on fit.

1000-W Quartz Tubular Infra-Red Lamp

In order to provide higher radiation intensities than those normally obtainable from an ordinary 250-W industrial infra-red lamp, Philips Electrical Ltd., of London, W.C.2, have developed what is claimed to be the first 1000-W quartz tubular infra-red lamp in Europe. Because of the thermal strain to which glass is likely to be subjected, the tube is made of quartz, which is not only particularly resistant to high temperatures but, because of its low coefficient of expansion, also lends itself to rapid local cooling.

The lamp has a power consumption of 1000 W and a diameter of only 10 mm. The length of the filament is approximately 290 mm. Thus, the power consumption per centimetre is in the region of 35 W. The life of the lamp is approximately 5000 hr, when operated on the rated voltage. If the closest arrangement—triangularly, with a distance of 15 cm between the lamps, centre to centre—is used, the ordinary 250-W industrial infra-red lamp can be installed to provide 2·5 W/cm^2. This

Good wishes to all
in industry
from
WAKEFIELD - DICK
for a very
pleasant Christmas
and a
most prosperous
New Year
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value is trebled when the new quartz lamps are used. This renders them eminently suitable for all those applications where a high temperature and/or extreme concentrations of energy are required. Furthermore, the small dimensions of the tube considerably simplify the question of installation.

Silver-Solder Paint

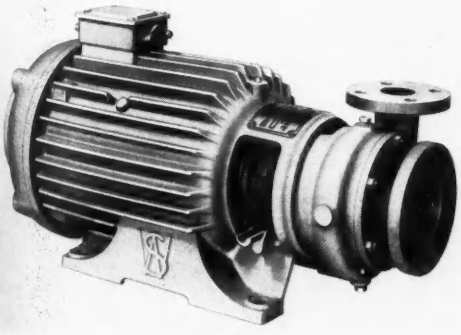
As a result of the experience gained in the manufacture of their soft-solder paints, a new material has been developed by Fry's Metal Foundries, Ltd., of Merton Abbey, London, S.W.19, for sweat-soldering in the field of low-temperature brazing. Designated F.E.F. silver-solder paint, this material, which is made from silver solder, finely powdered and mixed with silver-solder flux and a gelling agent, combines all the essential features of low melting, good fluidity, joint strength, and ability to join dissimilar metals. Moreover, it is suitable for individual jobs or for mass production, and can be used by unskilled labour.

A variety of heating methods can be employed, including spot-torch, soldering oven, muffle furnace, electro-gas, resistance, and high-frequency induction. The method of application is as follows :—After making sure that the work is clean and that the joint members fit closely (maximum capillarity is obtained with a clearance of between 0·002 and 0·003 in.), the paint is liberally applied in or touching the joint by means of a small brush or stylus. The assembly is then heated to a dull red, until the silver-solder paint is seen to flow, and finally the flux residue is removed.

Centrifugal Chemical Pumps

The latest addition to the line of pumps manufactured by Worthington-Simpson, Ltd., of Newark, Notts., is a range of centrifugal chemical pumps with outstanding resistance to many acids, alkalis, and slurries. These pumps are available in three different forms, i.e., types DFC and DMC, of monobloc construction, in which the pumps are combined as one unit with totally enclosed, fan-cooled motors, and type DC, in which the pumps are arranged for coupling to a special motor, engine, or belt drive, and supplied with a bare shaft, flexible coupling, or complete motor drive on a baseplate. A type-DMC pump is illustrated.

In each case the pumps are of extremely efficient design, and incorporate a number of distinctive features. Thus, for instance, construction is of either Worthite or 18/8/3 stainless steel. Of these materials, Worthite is a corrosion-resisting alloy which is greatly superior to standard austenitic steel, particularly insofar as the pumping of sulphuric acid is concerned, while 18/8/3 stainless steel is eminently suitable for mildly corrosive liquids or for applications in which the liquid itself is non-corrosive but where no contamination or discoloration of the liquid is permissible—as, for instance, in many food and dyestuff processes.



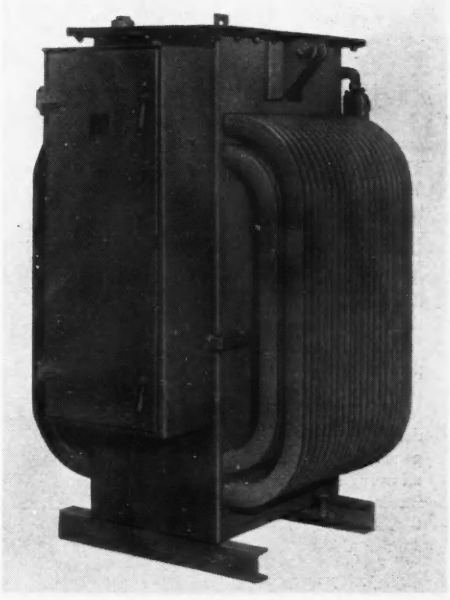
An important feature of these pumps is that the pump casing remains the same, irrespective of the seal used, while stuffing-box packing or mechanical seals can be interchanged simply by the use of adaptors to suit varying liquids. The mechanical seals can be supplied to suit either Worthite or 18/8/3 stainless-steel pumps, and are designed so that the stationary and rotating faces are kept together positively and any wear is taken up automatically.

The monobloc construction employed follows the method used by this company for many of their centrifugal pumps and air compressors and brings the advantage of such construction as an added feature, i.e., a single shaft linking motor and pump, thus ensuring perfect and maintained alignment, while the necessity for providing separate driving motors, baseplates, belts, pulleys, and couplings is entirely eliminated.

The range covers a maximum output of up to 675 gpm with heads up to 125 ft, depending on capacity. The maximum total suction lift at full capacities, including all pipe and valve losses, is 15 ft. Up to 18-ft suction lift can be obtained at lower capacities.

Selenium Rectifiers for Cathodic Protection

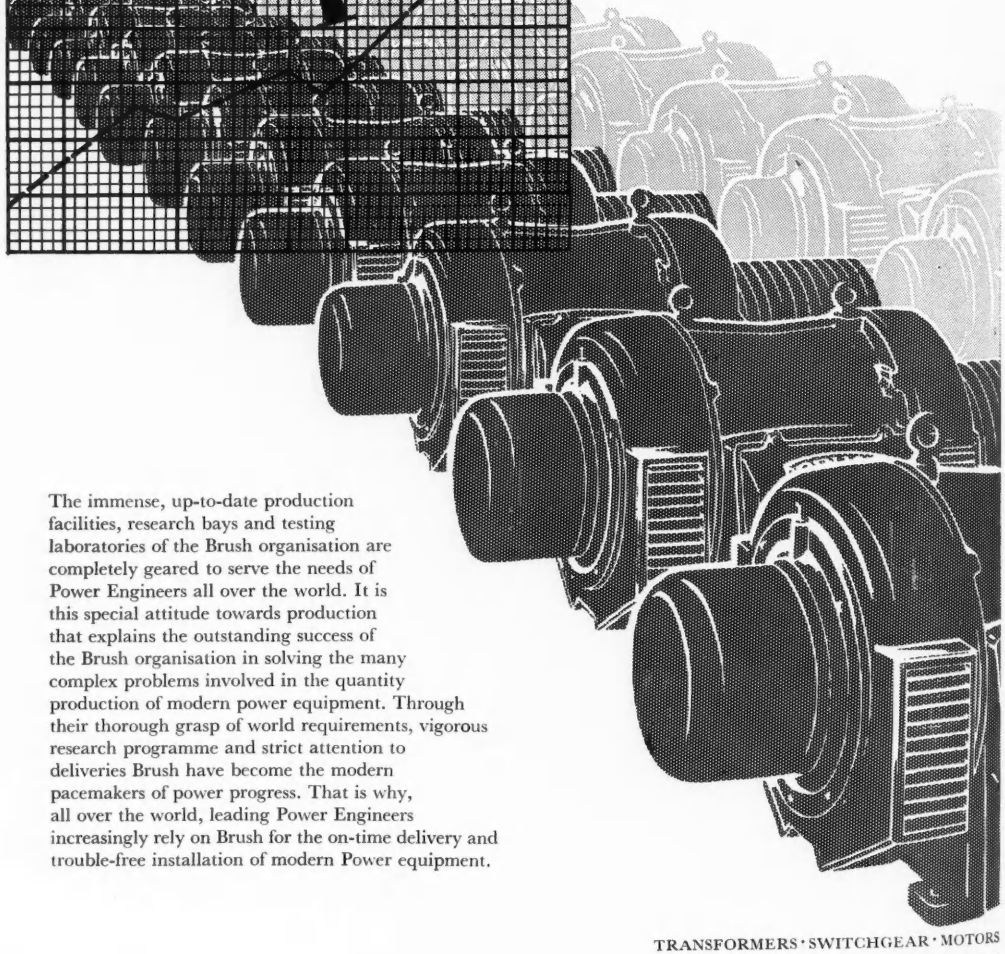
Metal-plate rectifiers for the cathodic protection of buried metal structures are now being supplied by the Hackbridge and Hewittic Electric Company Limited, of Walton-on-Thames, Surrey. This equipment is built according to a basic constructional design, but the rating and general electrical design are arranged to suit individual requirements. Voltage control is provided either by transformer tapping switches or by a voltage-regulating transformer.



The rectifier illustrated is a typical unit for providing a d.c. supply of up to 80 A, 6 to 60 V, at an ambient temperature of up to 55° C, and is intended for the cathodic protection of an oil pipeline in the Middle East. The rectifier stacks and regulating transformer are oil-immersed in a weatherproof tank for outdoor service, and the operating handwheel for the regulating transformer, together with the measuring instruments and terminals, is enclosed in a lockable box to prevent unauthorized interference.

THE POWER BEHIND BRUSH . . .

production



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CLASSIFIED ABSTRACTS

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AUTOMOBILE ENGINEERING

Disc Brakes for Motor Vehicles.

By F. J. BRADBURY and F. G. PARNELL. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, November 8, 1955, 17 pages, 20 illustrations.)

IT is well known that, when the speed of a motor vehicle is reduced by application of its brakes, heat is generated in the brake assembly. Bearing in mind space limitations, the ability of a brake to dispose of its heat or to withstand it without deterioration in braking efficiency is a measure of achievement in the brake design.

Like other mechanisms, the drum brake has a practical operating range which, if exceeded, usually results in reduced efficiency. Insofar as disc brakes are concerned, despite the fact that these have largely superseded drum brakes for aircraft landing-wheels, they have not as yet been generally applied to popular cars or to commercial vehicles. This is partly because there have been recent improvements in the drum brake, but it is also an indication of the difficulties encountered in producing a rationalized and reliable disc brake.

In this paper, after reviewing the development of disc brakes, a number of designs is discussed and the characteristics of disc brakes are compared with those of drum brakes. In particular, it is shown that the outstanding feature of the disc brake is its anti-fade characteristic, which gives it superiority over the drum brake in installations where space is restricted. The main part of the paper is devoted to a consideration of those factors which control design, and it is shown that rigidity is of paramount importance if a disc brake is to be used without an external servo-mechanism. Methods of obtaining the required degree of stiffness are discussed and curves are drawn to show the influence of caliper stiffness and other lost motions on displacement ratio and brake-pedal travel.

The application of disc brakes to commercial vehicles is discussed and details are given of an installation on a passenger service vehicle. Consideration is also given to the hand-operated disc brake on the transmission of commercial vehicles, and the paper outlines why this arrangement may become more general when disc brakes are used on the road wheels. Friction-pad characteristics are discussed in relation to rate of wear and recommended horse-power absorptions.

There are many problems associated with the installation and protection of disc brakes and these are outlined, with emphasis on the need for attention to caliper position and wheel-bearing design. It is also suggested that, although the exposed disc brake has given satisfactory results, it may become necessary to shield the disc, thereby resulting in either poorer cooling or complex ducting.

CORROSION

Microbiological Corrosion of Iron and Steel.

By D. M. UPDEGRAFF. (From *Corrosion, U.S.A.*, Vol. 11, No. 10, October 1955, pp. 44-48.)

THE corrosion of iron and steel is an electro-chemical process. It is now clear, however, that micro-organisms often exert effects which increase or decrease corrosion rates and which may be an important cause of corrosion under certain conditions.

In order for micro-organisms to promote corrosion, the environment must be suitable for their growth and multiplication. The essentials for microbial growth are moisture, a suitable pH, certain essential minerals (including phosphorus, potassium, nitrogen, sulphur, and iron), a carbon source (organic matter or carbon dioxide), and an energy source (sunlight, organic matter, or an oxidizable inorganic substance). All these essentials ordinarily are present when iron or steel comes into contact with any natural water, such as sea water, river water, lake water, or moist soil. Thus, it is hardly surprising that microbiological corrosion is a common and widespread process responsible for great economic loss.

In this paper, a critical review of the literature on microbiological factors involved in the corrosion of iron and steel is presented. A brief account of the historical aspects of the subject is given, together with a discussion of the mechanisms by which micro-organisms affect corrosion, a description of some typical examples of microbiological corrosion, and a discussion of methods used to prevent such corrosion.

It was found that, while micro-organisms do not corrode iron or steel, they often produce major physical and chemical changes in the environment. These changes may influence the electro-chemical processes responsible for corrosion and thus may markedly accelerate (or, under different conditions, decelerate) the corrosion rate.

It was found that micro-organisms sometimes coat metal surfaces, influence galvanic cells, affect pH or acidity, affect redox potentials, catalyse chemical reactions influencing corrosion, and change oxygen tension. A description of how anaerobic bacterial corrosion is carried out by sulphate-reducing bacteria is given.

Methods of alleviating microbiological corrosion include cathodic protection, protective coatings, germicide treatment of water, and alkali treatment. The selection of the anti-corrosion measures to be used in a given situation is difficult, necessitating an evaluation of all the mechanical, electro-chemical, and microbiological factors involved. It is also necessary to make an economic comparison of the various treatments possible. Methods for the control of microbiological corrosion will differ markedly in different locations.

GLASS ETCHING

Development of a Photo-Resist for Etching Designs in Glass.

By C. I. POPE and R. DAVIS. (From *Journal of Research of the National Bureau of Standards, U.S.A.*, Vol. 55, No. 3, September 1955, pp. 139-142.)

ETCHED glass scales and reticules are commonly produced by using a wax resist as a mask. However, workers in this field have a need for a light-sensitive coating, or resist, so that duplicate etchings may be made by contact printing, as in photography.

The problem of finding a suitable substance for making a light-sensitive resist is difficult, because the glass must be etched with hydrofluoric acid, which attacks all known light-sensitive coatings. Phenol-formaldehyde resin is known to be quite resistant to the action of hydrofluoric acid, and it seemed possible that a thin layer coated on glass might serve as a resist for hydrofluoric acid etching after development of the

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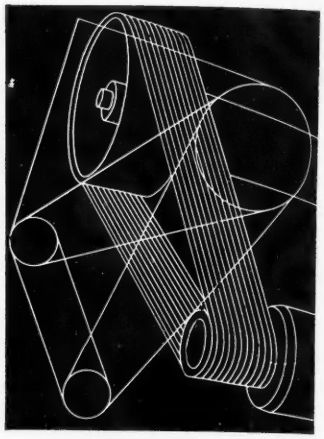

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3	2.89	4.08	5.00	5.75	7.07
5	2.24	3.16	3.88	4.77	5.48
7.5	1.82	2.58	3.16	3.65	4.47
10	1.58	2.24	2.74	3.16	3.88
15	1.29	1.83	2.24	2.58	3.16
25	1.00	1.41	1.73	2.00	2.45
50	.707	1.00	1.23	1.41	1.73
75	.578	.818	1.00	1.15	1.41
100	.500	.707	.866	1.00	1.23
150	.408	.575	.707	.818	1.00
200	.354	.500	.612	.707	.866
350	.268	.378	.463	.535	.655
500	.224	.316	.388	.447	.542
1,000	.158	.224	.274	.316	.388
1,500	.129	.183	.224	.258	.316
2,500	.100	.141	.173	.200	.245
5,000	—	.100	.122	.141	.173
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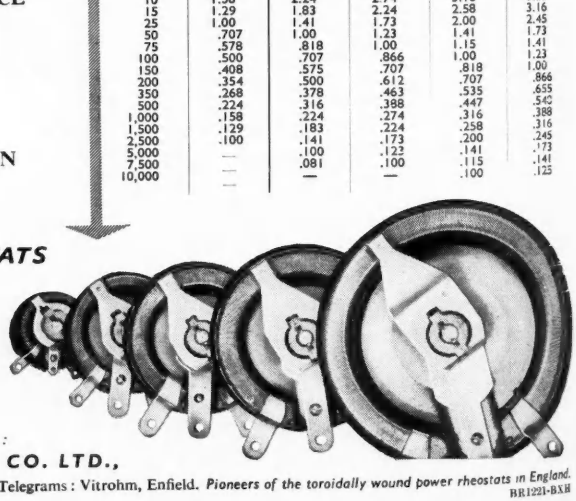

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image. In the course of the investigation described in this paper, it was found that the softness and tackiness of this resin was due in part to the presence of methyl alcohol in the formaldehyde solution used in its synthesis. The addition of methyl alcohol to trioxymethylene and phenol, in a concentration corresponding to that generally found in 40% formaldehyde solutions, yielded a soft, tacky resin. Therefore, trioxymethylene was used instead of a 40% aqueous solution of formaldehyde for the production of the phenol-formaldehyde resin in this work. Also, the alcohol-water developer used by Beebe, Murray, and Herlinger was not a satisfactory developer for the resin on glass. A resorcinol-formaldehyde resin was also made and was found useful as an additive in the phenol-formaldehyde resin.

It is generally a difficult problem to find a developer solution which will dissolve out the unexposed areas of the resin and not attack the exposed areas. The developer solution dissolved the unexposed light-sensitive resin quickly and yet did not attack the exposed resin, even if the development was extended several times beyond the normal developing time. Iodoform was found to be a very good sensitizer. The addition of 5% of the resorcinol-formaldehyde resin, based on the weight of the phenol-formaldehyde resin, improved the sensitivity and resist properties of the phenol-formaldehyde resin, although its presence was not necessary to make the phenol-formaldehyde resin function as a resist for etching glass.

The light-sensitive resist made with the phenol-formaldehyde resin will not withstand the action of concentrated hydrofluoric acid (48%). However, an etching solution containing hydrofluoric acid and phosphoric acid may be used for etching times up to 15 sec. An etching time of 5 sec was used to produce fine lines (10 microns wide). Even though the light-sensitive resist will not withstand a long etching time, deep lines may be obtained with the hydrofluoric acid/phosphoric acid etching solution by etching the glass several times for 3 or 4 sec, and washing and drying between each etch.

MACHINE-SHOP PRACTICE

The Use of Oxygen to Increase the Wear Resistance of High-Speed Steel Cutting Tools.

By G. I. YAKUNIN. (From *Stanki i Instrument*, *Russia*, No. 4, April 1955, pp. 21-22.)

FOLLOWING earlier suggestions on the use of gases for the purpose of cooling the cutting edge during the machining of metals, the author has carried out tests to establish the influence of oxygen on the resistance of the cutting edge and its period between regrinds.

These tests were carried out on a lathe by machining steel of 80 kg/mm^2 tensile strength with a conventional high-speed steel tool bit of standard cutting-edge geometry. At a depth of cut of 0·8 mm and a rate of feed of 0·2 mm per revolution the gas was supplied under a pressure of about 70 mm water gauge at a rate of about 20 litres/min. The cutting speed was varied in the range between 25 and 55 m/min. It was found that, at the lowest cutting speed, cooling with oxygen gave a period between regrinds of 544 min, whilst nitrogen reduced this period to 170 min and air to 99 min. To achieve a period of one hour between regrinds, oxygen cooling permits an increase in cutting speed of 68%, compared with air cooling.

Observations of chip formation and additional tests at different cutting speeds have elucidated the processes which take place in oxygen cooling. Two processes take place simultaneously on the surface of the cutting edge, i.e., the formation of an oxidized layer, and its destruction and removal. With an increased depth of the deformed layer at the cutting edge, the depth of the oxidized layer is also increased; when this attains a certain depth the layer cannot be removed at once, and from then onwards friction takes place on the surface of this layer. In practice this means that, if the cutting speed is high enough for an oxidized layer of sufficient thickness to be formed at once, a stabilized condition, without change in the nature of the chip surface, will result.

PROTECTIVE COATINGS

Abrasive-Jet Method for Measuring the Abrasion Resistance of Organic Coatings.

By A. G. ROBERTS, W. A. CROUSE, and R. S. PIZER. (From *ASTM Bulletin*, *U.S.A.*, No. 208, September 1955, pp. 36-41, 5 illustrations.)

ABRASION resistance is one of the most important properties determining the service performance of a protective coating for military aircraft. Thoroughly reliable measurement of this property in the laboratory has not yet been fully achieved.

This report describes a new method which has been developed for measuring the abrasion resistance of organic coatings on metals. The method utilizes a jet of fine abrasive particles, which, under controlled conditions of flow rate, pressure, distance, and angle, abrade through the coating to the substrate. Compared with other abrasion test procedures, in which loose abrasive particles fall, rub, or are blown against the test specimen, the smaller scale of operation of the new abrasive-jet method provides greater ease and rapidity in evaluating materials, generally better reproducibility (with the possible exception of the air-blast abrasion tester) through the use of a continuously fresh supply of abrasive particles under closely controllable conditions, greater versatility in readily providing a variety of test conditions, and the use of relatively simpler equipment. The method does not require photoelectric equipment, motors, or drive mechanisms; furthermore, it is applicable to all types of coatings, regardless of gloss, colour, or thickness, and it does not depend upon abrading an area of definite size. The method can distinguish significantly between materials difficult to differentiate by qualitative methods. The degree of correlation with actual service performance has not yet been established.

With this method, abrasion resistance is expressed in terms of the time required to abrade through a unit thickness of coating. Values are obtained with an average coefficient of variation of about 5%. The abrasion time depends strongly on the test conditions. It increases almost linearly with increasing nozzle-to-coating distance, decreases with increasing pressure, and decreases markedly with decreasing angle of abrasion from 90 down to about 30 deg.; at smaller abrading angles, the abrasion time rises again.

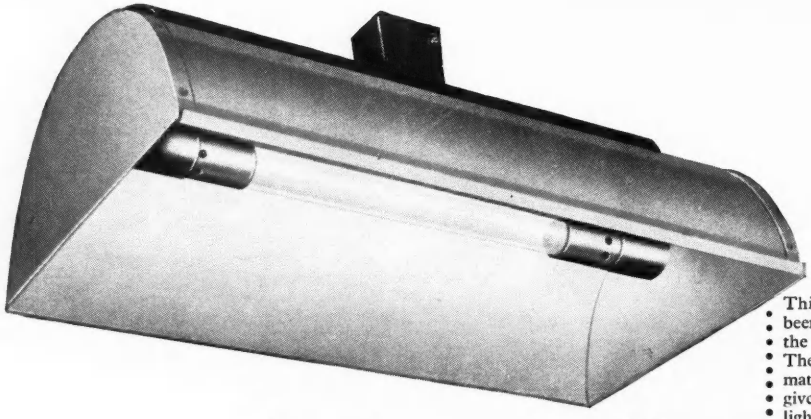
It is possible that different abrading angles may give different correlations with actual service. It is postulated that a 90-deg. test may simulate leading-edge erosion, while a 45-deg. test may more nearly simulate the scuffing type of wear encountered during maintenance operations.

SAFETY OF PERSONNEL

Electric Defibrillation.

By W. B. KOUWENHOVEN and W. R. MILNOR. (From *Power Apparatus and Systems* (*AIEE*), *U.S.A.*, No. 19, August 1955, pp. 561-567, 2 illustrations.)

A considerable number of electric-utility personnel dies each year as a result of accidental contacts with electric circuits. For many years manual artificial respiration has been the only accepted first-aid method for victims rendered unconscious by an electric shock. Analysis of accident statistics, however, shows that approximately one-third of those shock victims receiving artificial respiration with the promptness that should give promise of success nevertheless fail to recover. There



This reflector fitting has been specially designed for the kilowatt MA/H lamp. The trough reflector in matt, anodised aluminium gives a nearly-symmetrical light distribution.

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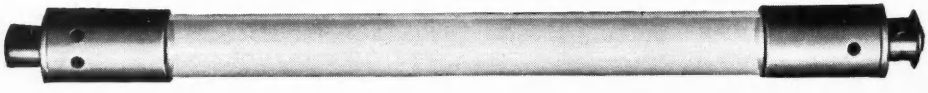

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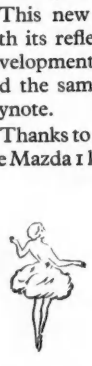

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is good reason to believe that many of these failures are due to the effects produced by the action of electric currents on the heart.

It has been clearly demonstrated that the heart is susceptible to electric currents. The passage of a small electric current through the heart may destroy its rhythm and throw it into a twitching state called ventricular fibrillation. In this state the circulation of the blood ceases and, unless heart action is promptly restored, death ensues.

Ventricular fibrillation may occur not only after electric shock but also in surgical cases, where the only known method of successfully arresting it is to send sufficient electric current through the heart to stop the twitching of the muscles. In the field it is naturally not feasible to open the chest and place the electrodes directly on the heart. Consequently, in the field, the electric current must be sent through the heart by electrodes properly placed on the surface (skin) of the chest. In addition, a field method must be one that may be safely applied to a normally beating heart, as the presence of fibrillation can only be detected by an electrocardiograph.

Because of the importance of this problem, a study has been made of the possibility of developing a method of recovering the fibrillating human heart without the need for opening the chest, and safe to apply in the field as well as in the hospital, together with defibrillating equipment which would be capable of functioning in either environment.

The results described in this paper may be summarized as follows :—

(1) The capacitor-discharge method of stopping fibrillation was found to be unsatisfactory because of its ineffectiveness after the heart had been in fibrillation for more than 30 seconds.

(2) The serial-defibrillation method, using pulses of alternating current, was found to be dangerous to normal hearts.

(3) The best method found for defibrillating the ventricles was a single application of 60-cycle alternating current lasting approximately 1 sec.

(4) The most effective direction of flow through the chest of the defibrillating a.c. current is the longitudinal, head-to-foot direction.

STRENGTH OF MATERIALS

Rupture of Heat-Resistant Alloys in Flame Gas Atmospheres.

By E. W. Larocca. (From *Jet Propulsion, U.S.A.*, Vol. 25, No. 8, August 1955, pp. 396-399, 7 illustrations.)

The application of rate-process theory to the high-temperature failure of metals by rupture and creep has been the subject of much research. The research described in this paper was conducted in an effort to determine the effects of combustion atmospheres on the rupture life of a stressed metal, when the metal is in the presence of, and heated by, a gas flame, with the products of combustion available for possible diffusion.

The materials selected for the investigation were commercially available heat-resistant alloys, i.e., chromel (60 Ni, 15 Cr, 22 Fe, 1 Si, 0·6 Mn), and nichrome (80 Ni, 17 Cr, 1·3 Si, 0·6 Fe, 0·6 Mn). Both materials were in the form of wire, 0·051 in. in diameter, and were used in the cold-drawn (as-received) condition, without further heat treatment or annealing, to emphasize any effects of prior cold working. The room-temperature tensile strength of the chromel material was 115,000 psi, and of the nichrome material 107,400 psi.

This paper reports the rupture of these heat-resistant materials, stressed in combustion atmospheres, at temperatures between 920 and 1150° C in a burning propane flame. Rupture times of approximately 30 seconds to 1 hour were obtained, covering a range of 10 stresses between 4300 and 9680 psi. The data were compared with conventional stress-rupture and creep data and are in general agreement. Experimental evidence indicated that the activation energy of the stress-rupture process, under the above conditions of heating and atmosphere, is not constant and may be stress-dependent.

It is concluded that the rate-process equation may be useful in the interpretation of stress-rupture data, but that extrapolation is not accurate. In this connection, it is believed that further research will be required, to disclose the relations between stress and temperature, activation energy and stress, and the true meaning of the pre-exponential, if the rate-process equation is used for the analysis of stress-rupture data under the conditions of heating and atmosphere described.

WELDING

The Effects of Nitrogen in Argon-Arc Welding Atmospheres.

By H. C. Ludwig. (From *The Welding Journal, U.S.A.*, Vol. 34, No. 9, September 1955, pp. 409s-414s, 8 illustrations.)

The nitrogen content of argon shielding gas is critical in the arc welding of low-carbon mild steel. A nitrogen absorption-desorption mechanism in molten steel and iron causes weld porosity. This paper describes the effects of nitrogen in argon atmospheres on consumable mild-steel electrode arc-welding deposits and provides the tolerance limit of nitrogen contents in the shielding gas.

The solubility of nitrogen in iron has been extensively investigated because of its influence in the making and working of steel. However, present-day knowledge of nitrogen solubility in the iron and steel liquid phase remains limited, particularly with respect to the presence of nitrogen in gas mixtures.

The laboratory investigations described in this paper have been made to determine the solubility of nitrogen in steel arc-weld metal when using argon-nitrogen atmospheres. The results indicate greater chemical activity than that expressed by a square-root law of gas solubility with respect to nitrogen pressure in the arc-welding atmosphere. The solubility of nitrogen at one atmosphere was found to be in the range of 0·038 to 0·041% by weight. The average found corroborates the accepted value of nitrogen solubility in pure iron at 1540° C under equilibrium conditions.

Not all the nitrogen absorbed by the molten weld metal is retained. As the metal cools to the solidus, nitrogen is released to form gross porosity. The porosity has been found detrimental above about 1% by volume nitrogen in the argon-arc welding atmosphere. These data explain the reasons for the high argon-purity requirement in the application of this gas to the shielding of steel welding arcs.

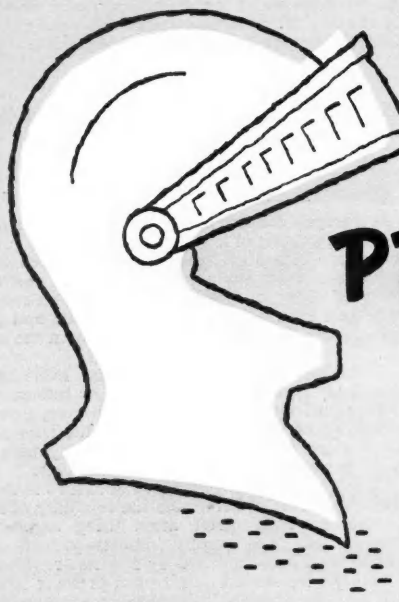
Among others, the following conclusions are drawn :—

(1) Nitrogen is dissolved by low-carbon mild steel in welding arcs of argon-nitrogen atmospheres and partially retained on cooling.

(2) The amount of fixed nitrogen retained in the weld deposits described is altered only slightly by the arc heat-energy input and its distribution.

(3) Nitrogen initially present in the welding electrode material can be significantly reduced by restricting the nitrogen to below a partial pressure of 0·005 atm in the argon-arc gas shield.

(4) From the practical point of view, argon used in inert-gas-shielded consumable-electrode processes should contain no more than 1·0% nitrogen and preferably less than 0·5%. The nitrogen may be an impurity of the cylinder argon and/or nitrogen may be introduced from the natural atmosphere which is in proximity to the argon gas shield.



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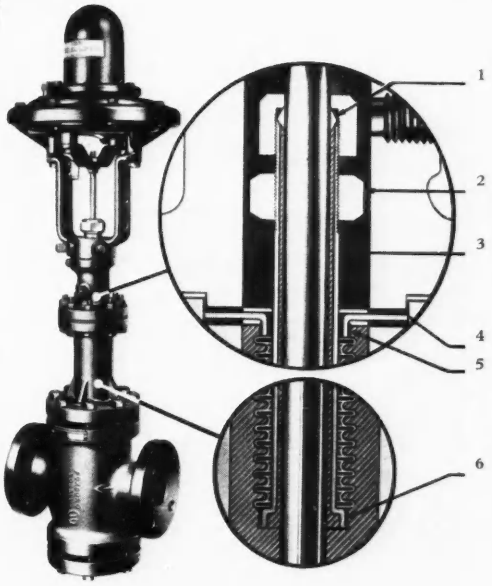
These hoists can be supplied either for fixed mounting, or with a trolley carriage to suit standard I-beams. The trolley may be arranged either for push travel, hand-chain, or power travel, depending on requirements, and a variety of lift heights and lifting speeds is available, to cater for the needs of practically every type of installation.

When required, the hoist can be provided with a micro-speed motor to give a creeping speed in addition to the normal speed. This feature is invaluable when handling loads which require great care or precision for placing gently into position. The unit is of all-steel construction, enclosed in a steel housing, with the motor assembled inside the drum. The motor automatically engages or releases the brake, which is coupled directly to one end of the motor shaft. The gearbox, brake, and electrical contacts are all enclosed in the housing. A rope guide ensures correct winding of the rope on the drum, which operates in conjunction with a limit switch to prevent overwinding and overlowering.

PACKLESS CONTROL VALVE

The range of their " Stabilflo " control valves has been further extended with the introduction by Foxboro-Yoxall Limited, of London, S.W.19, of a pneumatically operated control valve with a positive leakproof metallic bellows built in below the conventional stuffing box. The normal stuffing box is retained and becomes an emergency safety seal. The valve is designed for use on those processes involving liquids which cannot be permitted to escape (even in the minute amounts which might pass the conventional packing gland) because of the loss or danger involved. Such fluids include certain toxic, corrosive, and explosive gases, and many pharmaceutical chemicals. The valve also meets the requirements of processes under vacuum where no leakage is permissible because of vacuum loss or contamination from the atmosphere.

The bellows seal is housed in an adaptor spool assembled between the body and the bonnet of a " Stabilflo " valve. As shown in the illustration, a close-clearance sleeve (3) surrounds the valve stem, the upper end of the sleeve being locked to the valve stem by a specially designed ferrule and locknut (1). A make-up nut (2) is welded to the sleeve for tightening the compression fitting. The lower end of the sleeve (6) is seam-welded to a bellows, the upper end (5) of which is seam-welded to a flange (4) clamped between the gasketed bonnet and the adaptor-spool flanges. A positive seal against the line fluid is thus provided, while the bellows expands and contracts with the reciprocating action of the valve stem.



The bellows has been designed to give an exceptionally long life and will function perfectly even after continuous difficult service. Furthermore, it is protected against possible stroke overrange damage by virtue of its ability to handle the maximum stroke of the valve with a wide safety margin. The valve may also be used as a conventional control valve. The bellows seal is easily removed, leaving the stuffing box to act as a seal in the normal manner.

HYDRAULIC-FEED SURFACE GRINDER

A new hydraulic-feed surface grinder, with an 8 × 24 in. working surface of table and with a capacity of 12 in. under a full 10-in. diameter wheel, has been developed by the Gallmeyer and Livingston Company, of Grand Rapids, Michigan. The machine is built around a heavy, rugged, one-piece column and base for permanence of alignment between vertical headways and cross-travel ways. The head of the machine has

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Here is an axle housing for a famous firm, cast in Ley's 'Black Heart' malleable; with cored passages to suit modern lubrication practice:

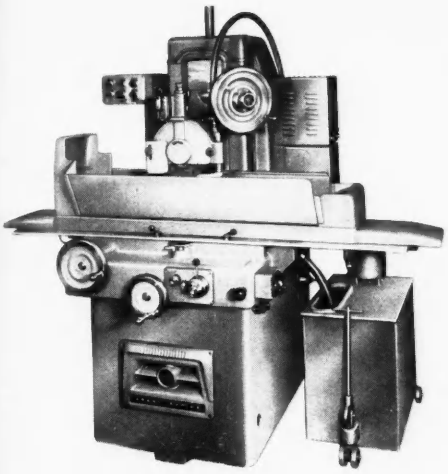
LEY'S 'BLACK HEART' MALLEABLE CASTINGS:		LEY'S 'LEPAZ' MALLEABLE CASTINGS:	
Elongation:	18%	Elongation:	6%
Yield Point:	16 tons p.s.i.	Yield Point:	21 tons p.s.i.
Tensile Strength:	24 tons p.s.i.	Tensile Strength:	35 tons p.s.i.

We offer your designers the full collaboration of our engineers.

LEY'S MALLEABLE CASTINGS CO LTD., DERBY. TELEPHONE: DERBY 45671

EUROPE'S LARGEST MALLEABLE PRODUCERS

LEY'S



a precision grease-sealed ball-bearing spindle carried on protected preloaded ball-bearing ways for ease of vertical movement and fine accuracy. Exposed bearings are protected by bellows-type guards.

Vertical movement is effected by a handwheel on the head. A large, outer handwheel is used for coarse vertical adjustment of the spindle head. The latter wheel is graduated in thousandths of an inch, widely spaced. An adjustable pointer can be set for convenient readings if greater accuracy is not desired. The smaller handwheel is graduated in tens of thousandths of an inch. One revolution of the large handwheel provides 0·060 in. of vertical movement, and of the small handwheel 0·012 in. of vertical movement. Infinitely variable longitudinal table speeds, ranging from 3 inches to 125 feet per minute, are available, and can be changed immediately by means of a conveniently located control on the front of the saddle. A handwheel for operation of the longitudinal table movement is also standard equipment and is automatically disengaged as the hydraulic feed becomes operative. The hydraulic cross-feed is variable up to a maximum of $\frac{3}{8}$ in. per table reversal. The amount of cross-feed may be quickly established by means of a control conveniently located on the control panel on the front of the saddle. The cross-feed of the machine may also be operated by means of a handwheel which is conveniently located on the front of the saddle, and which becomes automatically disengaged when the hydraulic cross-feed is in operation. A variable-speed continuous cross-feed for dressing or positioning is standard equipment.

The amount of longitudinal and transverse table movements is sufficient to permit clearing the entire working surface of the table with the standard $10 \times \frac{3}{4} \times 3$ in. grinding wheel. The grinding-wheel spindle is driven through V-belts by a 2-hp motor mounted on an adjustable bracket attached to the head of the machine so as to provide two usable spindle speeds.

HIGH-TEMPERATURE LABORATORY FURNACE

A special design of laboratory furnace, using a new development in silicon carbide elements, i.e., a heating element in the same material as " Silit " rods but in the form of a tube, is announced by Siemens-Schuckert (Great Britain) Ltd., of Brentford, Middlesex. The advantages of long life and simple operation, inherent in the " Silit " rod, are also present in the tube, with the important feature that uniform distribution of temperatures up to 1500° C is ensured, owing to the form of the element.

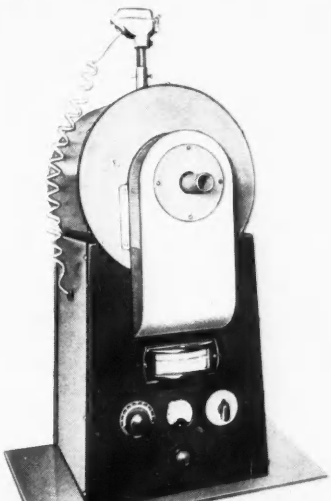
Like the " Silit " rods with thickened ends, the " Silit " tube has a larger external diameter at the end portions and a central heating portion. A " working tube," in which the material to be treated is placed, is fixed in the centre of the " Silit " tube. The latter is surrounded by another ceramic tube and the whole fitted into the steel cylindrical body, with suitable insulating material. This working tube, which has an internal diameter of 27 mm, is made of an impervious refractory material which therefore permits the use of a reducing atmosphere, if necessary, without fear of the element being attacked by the atmosphere.

The electrical supply is connected to the thickened ends of the " Silit " tube, which, when necessary, may be very easily withdrawn after removal of the terminal cover, connectors, and working tube; this does not disturb the thermal insulation, which is positioned by the outer tube.

To assist accurate temperature control, the voltage applied to the heating element can be reduced by means of a tapped transformer, thus allowing the input to the furnace to be reduced so that it just maintains the furnace temperature.

As the electrical resistance of silicon carbide rods and tubes increases with age, the secondary of the above-mentioned transformer is also tapped, permitting the secondary voltage to be increased when " ageing " occurs. This tap changing is achieved by altering the position of a swing link.

All the electrical equipment is housed in the bench-mounting stand of the furnace and includes the tapped transformer, tapping switch, main contactor, pilot lamp (to indicate " furnace on "), manual power regulator, and ammeter.



The manual power regulator is an electro-mechanical device which periodically switches on and off the supply to the furnace for intervals of time which can be preset. By using this device in conjunction with the tapped transformer extremely accurate temperature control can be obtained.

As the maximum kW input to the heating element has to be strictly adhered to, an ammeter is fitted in the transformer primary circuit; the maximum primary current at various temperatures can thus be determined.

THE TOUGHENED CORE
The illustration shows a 4-row Timken balanced-proportion tapered-roller bearing ; like other Timken bearings, this is made of special case-hardened high-alloy steel, heat-treated to provide a toughened shock-resistant core.
Among the other advantages of the Timken balanced-proportion bearing are that, in relation to its outside diameter, it has a large bore—admitting a big roll neck—and has a very great load-carrying capacity.
MADE IN ENGLAND
Regd. Trade Mark: TIMKEN
TIMKEN
TAPERED-ROLLER BEARINGS

BRITISH TIMKEN LTD.,

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NEWS OF THE MONTH

PERSONAL

Mr. G. W. Alexander, B.Sc., M.I.E.E., A.M.I.Min.E., has been appointed chief engineer of Powell Duffryn Ltd. He has relinquished his executive position with Powell Duffryn Technical Services Ltd., but remains a member of the Board of that company.

Mr. G. R. Blakely, B.Sc.(Eng.), M.I.C.E., M.I.Mech.E., M.I.P.E., general works manager of G. A. Harvey & Co. (London) Ltd., Greenwich Metal Works, London, S.E.7, since 1952, has been elected to the Board of the company as works director.

Mr. A. H. Chandler has been appointed by the London Division of the Central Electricity Authority as superintendent of the West Ham Power Station.

Mr. D. J. Crabbe, works director of the Brazil factory of the Dunlop Rubber Co. Ltd., since last year, has returned to Dunlop's Speke, Liverpool, factory as chief engineer.

Mr. J. P. Ford, managing director of The Brush Group's export companies for the past seven years, chairman of the Institute of Export, has joined Charles Colston Ltd., 3 Mill Street, London, W.1, the company formed by Sir Charles Colston earlier this year, as managing director.

Mr. W. T. Hind has been appointed production supervisor of all manufacturing plants, other than for shavers, of Remington Rand Ltd. He will operate from the head office at Commonwealth House, 1 19 New Oxford Street, London, W.C.1. **Mr. W. Carter** has been appointed general factory manager of the typewriter plant at Hillington, Glasgow.

Mr. J. O. Hitchcock, B.Sc., F.R.Ae.S., F.I.M., sales director of The Mond Nickel Co. Ltd., Thames House, Millbank, London, S.W.1, has been elected a Member of the Institution of Mining and Metallurgy.

Mr. J. Jones, managing director of The National Gas and Oil Engine Co. Ltd., has been appointed deputy chairman of the company from January 1st, 1956, when he will relinquish his present position and be available to all companies of The Brush Group Ltd. in a consultative capacity. **Mr. S. Webster,** deputy managing director, will be appointed managing director of the company from January 1st.

Mr. J. A. R. Kay, F.R.Ae.S., director of A. V. Roe & Co. Ltd., Manchester, and executive assistant to Sir Roy Dobson, the managing director, has been appointed general manager of the company.

Mr. E. J. Kimmins has been appointed deputy director-general (operations), and **Mr. F. Marsh,** deputy director-general (physical planning) in the production department at headquarters of The National Coal Board. **Mr. J. H. Plumtre** has been appointed deputy director-general (economic planning) before taking up another position with the Board.

Mr. H. Dale Langley, B.Sc., has been appointed technical manager of Square D Ltd., 100 Aldersgate Street, London, E.C.1, the recently formed subsidiary of the American Square D Company.

Mr. R. F. Lansdown has been appointed chief mechanisation engineer in the production department at the headquarters of The National Coal Board.

Mr. Peter J. A. Lubbock, formerly with the Chaseside Engineering Co. Ltd., has been appointed publicity officer of Langley Alloys Ltd., Langley, Slough, Bucks.

Mr. M. R. Neville has been appointed group publicity manager of British Industrial Plastics Ltd., Oldbury, near Birmingham.

Mr. M. E. O'Keeffe Trowbridge, B.Sc., A.C.G.I., A.M.I.Chem.E., who has been in charge of the technical, technical sales and project engineering activities of Sharples Centrifuges Ltd., Woodchester, Stroud, Gloucestershire, has been elected to the Board of the company.

Mr. Gerald M. Palmer has joined Vauxhall Motors Ltd., Luton, Beds., as an assistant chief engineer. Mr. Palmer will concentrate primarily on development of passenger cars. As one of a small group of senior engineering executives, he will be responsible to Mr. Maurice Platt, chief engineer of the company.

Mr. J. D. Parsons has been appointed Director of Ordnance Factories (Explosives), Ministry of Supply.

Mr. E. S. Pettyjohn, director of the Institute of Gas Technology, affiliated with the Illinois Institute of Technology, 17 West 34th Street, Chicago, 16, Illinois, since 1945, has resigned. **Dr. Henry R. Linden,** research director, has been appointed acting director, to serve until a successor to Mr. Pettyjohn is selected.

Mr. James Royce has joined Hedin Ltd., Commerce Estate, Raven Road, London E.18, to take charge of manufacturing of furnaces, including high-temperature furnaces.

Mr. Maurice H. Rutledge has resigned from his position with the Filtration Division of Newall Group Sales Ltd., and has been appointed sales manager of the " Filtrall " Division of C. A. Swales (Filters) Ltd.

Mr. Philip A. Singleton has resigned from the Board of Monsanto Chemicals Ltd., 8 Waterloo Place, London S.W.1, in order to take up a new appointment with the Monsanto Chemical Company, St. Louis, U.S.A. **Mr. D. R. Mackie,** commercial director, has been appointed acting managing director of the company.

Dr. David Martineau Tombs, M.Sc., Ph.D., A.M.I.E.E., until recently Senior Lecturer in Telecommunications at the Imperial College of Science and Technology, London, has been appointed to take charge of a newly constituted research department of Hoover Limited, Perivale, Middlesex.

Lord Tweedsmuir, O.B.E., LL.D., has been re-elected President of the Federation of Commonwealth and British Empire Chambers of Commerce, 69 Cannon Street, London, E.C.4.

Mr. Arthur Walker has been appointed managing director of Henry Berry & Co. Ltd., Hydraulic Engineers, Leeds. **Mr. D. Coley** has joined the Board of the company and now holds the appointment of chief engineer.

Mr. H. A. A. While, London manager of The United Steel Companies Ltd., 8 Grosvenor Gardens, London, S.W.1, has been elected to the Board of the Workington Iron and Steel Co. Ltd.

Mr. B. S. Worrall, A.M.I.E.E., has been appointed sales manager, electrical equipment, to Henry Meadows Ltd., Fallings Park, Wolverhampton.

BUSINESS NOTES

The Federation of Engineering Design Consultants, a new technical and professional association, has been formed with temporary headquarters at St. Stephen's House, London, S.W.1. Mr. Ray Body, of E. G. Irwin & Partners Ltd., is chairman of the Federation.

The Scientific Instrument Manufacturers' Association, 20 Queen Anne Street, London, W.1, has formed a Nucleonics Group. Mr. R. Y. Parry, of Ekco Electronics Ltd., has been elected

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that fault
with the
AIRSONIC
INDUSTRIAL STETHOSCOPE
This new acoustical instrument ends guesswork in locating and detecting faults. The AIRSONIC is acutely sensitive to changes in the characteristic rhythms or sounds of mechanical and electrical equipment; of pipelines above or below ground; of metals, plastics and other materials. Whether known to exist or still unsuspected, the AIRSONIC will pin-point the exact trouble spot—tracing unwanted noises, revealing leakages, discovering unsound joints, detecting excessive wear or metal fatigue.
"Tune-in" to trouble . . .
The AIRSONIC tunes in to trouble, tunes out unwanted frequencies. Saves time and labour in plant maintenance, avoids costly breakdowns. AIRSONIC, the infallible fault-finder, is compact, non-electric—and quite inexpensive.
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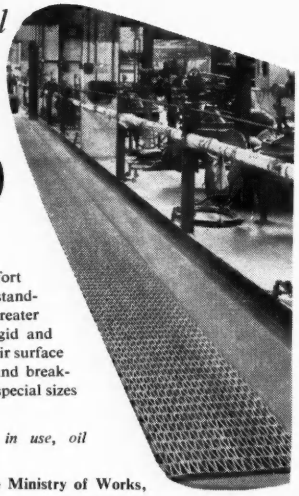
TYPROD MATS

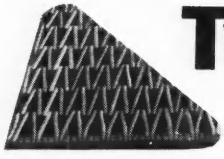


"Typrod" Mats give comfort where it is most needed, arrest standing fatigue and ensure greater industrial efficiency. Both rigid and roll up types are made, and their surface properties prevent accidents and breakages. In standard sizes, or in special sizes and shapes to order.

Where machine lubricant is in use, oil resisting material is supplied.

Guaranteed. Contractors to the Ministry of Works, Ministry of Supply, British Transport Commission, etc.

The link between efficiency and comfort



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BOULTON PAUL AIRCRAFT LTD.
WOLVERHAMPTON

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Very probably we do, as we have a wide circle of friends. However, not all our friends are fully acquainted with our expanding interests in the field of industrial instrumentation and we are always glad to talk about ourselves (in a very modest manner, of course).

Do you wish to measure loads on machine presses, tension in tie bars or guy ropes? Are you having difficulty in accurately measuring small displacements? Perhaps you wish to count objects leaving your production lines or to time processes accurately. Perhaps pressure measuring equipment would interest you. If you wish to obtain a stabilised power unit to drive some of your existing equipment we can help you there, too.

As the Electronics Division of a large aircraft company, we are in a unique position to offer a specialised service throughout all branches of industry.

Our catalogue has details of all our equipment - stabilised power units, load cells and load rings, strain gauge and displacement transducer monitoring equipment, six-channel film recorders, counters, timers etc., and automatic manometers. Oh, yes, and we make a very good line in instrument cases too. Drop us a line; we are sure we can help you.

Yours faithfully
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Air compressors

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chairman, and Mr. H. A. Luss, of Isotope Developments Ltd., vice-chairman of the Group.

The Association is organising an exhibition entitled "Atoms, Electrons and Industry," to be held in Bristol from June 6th to 8th to demonstrate the importance of applications of atomic energy to industrial and wider uses.

Metropolitan-Vickers Electrical Co. Limited have recently completed the reorganization of their infra-red demonstration section in its new location on the first floor at 132-135 Long Acre, London W.C.2.

The company were pioneers in the development of industrial infra-red lamp plants for paint stoving on aeroplanes in the last war and this demonstration room still includes a lamp plant, although emphasis is now on the tubular sheathed element type of plant which, in addition to being more robust, also permits higher loadings per square inch.

All the plants are operative and have a total connected load of approximately 90 kW. The equipment includes a variable speed mono-rail conveyor, a 6-ft. spray booth, test panels and associated instruments.

Many organizations already have availed themselves of the demonstration section to test the suitability of infra-red heating in connection with their products.

Heating engineers are in attendance and are dealing daily with industrial applications where heat processing is required for paint stoving, moisture extraction, preheating and curing.

The British Thomson-Houston Co. Ltd., Rugby, have formed a new company, The British Thomson-Houston Co. Central Africa (Private) Ltd., with offices in Salisbury, Bulawayo, and N'dola. Mr. K. C. Ford, B.Sc., A.M.I.E.E., who has been appointed general manager, is well known in Rhodesian engineering circles, where he has spent a number of years as the BTH Co.'s regional representative.

In addition to Mr. K. C. Ford, Mr. G. R. A. Johnson, of Messrs. Johnson & Fletcher, is included on the Board of Directors.

The BEAMA Catalogue, the third edition of which has now been published, is recognised throughout the world as the most comprehensive buyers' guide of the products and services of the electrical manufacturing industry. Its 1034 pages contain detailed descriptions of the products of the industry in more than 1200 product groups, and a trade directory. It also includes a glossary in five languages—English, French, German, Portuguese, and Spanish. More than 15,000 copies of this new edition of the Catalogue are now being sent to every country in the world, to Embassies and Trade Commissioners, overseas buyers, public utility officials, distributors and wholesalers. The BEAMA is one of the few trade associations which maintains overseas committees in various countries throughout the world, notably the Commonwealth. It is mostly from these committees that the names of overseas recipients of the Catalogue are obtained.

The Catalogue is in three sections. They are: "Electrical Power Plant"; "Electrical Equipment in Industry, Transport and Communications"; and "Domestic and Commercial Electrical Appliances, Lighting Accessories and Installations." For easy reference each section is printed in a different colour.

Every technical term used in the Buyers' Guide is in five languages. The classified Buyers' Guide lists the complete range of electrical and allied equipment manufactured by member firms of the BEAMA, and the Trade Directory gives the principal names and addresses and full details in the United Kingdom of all member firms of the Association. The name, address, telephone number and telegraphic address of more than four thousand overseas branches, representatives and agents throughout ninety territories in the world are included in the Catalogue.

The Catalogue is published for the BEAMA by Iliffe and Sons Ltd.

The British Reinforced Concrete Engineering Co. Ltd. announce that arrangements have been made with the Lancashire Steel Corporation Ltd., their largest supplier of steel wire, for the establishment of a company which will be owned in equal shares by B.R.C. and L.S.C.

This new company will be known as B.R.C. Steel Co. Ltd., and will carry on the business of wire drawing in a factory which is to be erected on B.R.C.'s property at Stafford. The output will be solely for B.R.C.'s own consumption, and will materially assist in providing steady supplies of the steel wire which is the principal raw material used in their business.

The Belark Tool & Stamping Co. Ltd., have moved to 9 Carnaby Street, London, W.1, Tel. No. GERrard 2178.

Vacuum Oil Co. Ltd., Caxton House, London, S.W.1, has changed the name of the company to Mobil Oil Company Ltd. There will be no change in the ownership, management or policy of the company.

The Shirley Tools & Engineering Ltd., Elgin Road, Freemantle, Southampton, announce that their new telephone number is Southampton 21881.

The General Electric Co. Ltd. have opened a new depot at Magnet House, Derby Street, Preston, under the management of Mr. R. G. Galloway. Tel. No. Preston 57871/2.

The National Aeronautical Establishment at Bedford will be known, as from 1st December, as the Royal Aircraft Establishment, Bedford. Set up in 1946 to supplement the work of the R.A.E., Farnborough, it is equipped with some of the most up-to-date wind tunnels.

Pressure Die Casting Industry. With a growing demand for its products, the Pressure Die Casting industry has had to look for ways to increase its productivity. Details of some of the measures it has taken are revealed in "A Review of Productivity in the Pressure Die Casting Industry" just published by the British Productivity Council. The Review shows that automation has become an increasingly prominent feature in this industry, and although the completely automatic pressure die casting factory is probably a long way from realisation, the indications are that the techniques of automation will be employed to an increasing extent.

A particularly important feature in developing the efficiency of the industry has been an improvement in the relationship between the die caster and his customer. All too prevalent in pre-war days was the practice of a die caster receiving instructions to produce a casting to specified dimensions without any thought having been given by the customer to the economics of design. Today, a close degree of co-operation exists between the die caster and the majority of his customers with the consequent production of castings which combine the essential requirements of design with the most economical method of production.

Among developments which are referred to in the Review are the close attention which has been paid in recent years to technological details, such as water cooling of dies, the composition of alloys and also to such matters as materials handling. Reference is also made to other techniques including estimating and costing, work study and plant maintenance. Copies are obtainable from the British Productivity Council, 21, Tothill Street, London, S.W.1. Price 2s. 6d.

POROUS METAL BEARINGS

Quite apart from its excellence as an instructional film on the design and application of porous metal bearings, "The Fundamental Principles of Self-Lubrication," devised by Bound Brook Bearings Ltd., of Lichfield, Staffs., is noteworthy for the fact that it tells its story without a word or hint of advertising or other form of self-glorification. Rigidly eschewing conventional approaches to commercial film technique *via* Publicity Departments, Bound Brook Bearings Ltd., experts on porous metal bearings, have wisely decided to let other experts develop their theme. As a result, expert production by Dr. D. Ward, for Technical & Scientific Films Ltd., in association with the Film Producers Guild Ltd., and expert scripting and direction by Harry Dance have combined to make an expert film, interesting, accurate, and informative. By a skilful and intelligent blend of straight photography of startling brilliance and excellently conceived and executed animated diagrams, graphs, and drawings, the film admirably reviews the elementary principles of friction and lubrication in solid journal bearings and porous metal bearings, within the parameters of viscosity, load, and speed,

$$\frac{d^2\theta}{dx^2} + \frac{1}{x}\frac{d\theta}{dx} - \frac{\theta}{x^2} = -\frac{V}{D}$$

$$p\left(\frac{d\theta}{dx} + \frac{1}{m}\frac{\theta}{x}\right) = M_a$$

$$n\left(\frac{\theta}{\lambda} + \frac{1}{m}\frac{d\theta}{dx}\right) = M_a$$

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And after a session with heads wrapped in wet towels, our design department will emerge triumphantly with the springs calculated to do the job better than any other. It's as well to call us in at the design stage, you know. More than thirty years facing up to this sort of thing has taught us most of the answers.

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Consider the strength of a Heavy Duty Dumper

Dumpers used for big excavating and quarrying projects have to lead a tough life *and* a long one. Transmission components in particular are subject to the grinding wear and tear of heavily loaded vehicles running at high speed and climbing rough, rock strewn country. It is because of the need for calculated, unfailing strength in the transmission units of the Euclid Dumpers manufactured by Euclid (Great Britain) Ltd., illustrated above, that Lloyds with their unsurpassed facilities for scrupulous control at every stage of production are called upon to cast these vital components.

TYPICAL LLOYDS STEEL SPECIFICATIONS USED FOR TRANSMISSION PARTS
Grade Y, 0.75% *Cr, hardened and tempered, Yield Stress* 30/40 *t.s.i.; Ult. Stress* 45/55 *t.s.i. ; Elongation* 20/15%; *R.O.A.* 40/30%.
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and clearly and dispassionately demonstrates the advantages and limitations of such bearings.

This production (16-mm, sound, running time 31 min.), an outstanding example of the immense value of motion pictures as an educational medium, is available on free loan, on application to Bound Brook Bearings Ltd.

"PROBLEMS OF AIRCRAFT PRODUCTION"

The Fourth Annual Conference on "Problems of Aircraft Production" is being promoted by the Southern Section of the Institution of Production Engineers at the University of Southampton (by kind permission of the Vice-Chancellor), on Friday and Saturday, 6th and 7th January, 1956.

The theme of this Conference will be: "Speeding Aircraft Production," and emphasis throughout the Conference will be placed on methods which will enable reductions to be made in the time taken to produce aircraft.

A feature of the 1956 Conference will be the inauguration of "The Lord Sempill Paper." It is intended that the presentation of this Paper shall be an annual event to mark not only Lord Sempill's lifelong interest in aviation, but also his association with the Institution of Production Engineers (of which he is a Past President) since its formation.

The author of the 1956 Lord Sempill Paper is Sir Roy Fedden, M.B.E., F.R.S.A., D.Sc., F.R.Ae.S., and his subject will be "The Nation's Aircraft Needs." He will examine broadly the technological and economic factors which influence the development and marketing of aircraft, and will refer to the influence—sometimes good, sometimes bad—of Government policy.

Mr. H. G. Gregory, M.I.Prod.E., manager of the Northern Factories of Fairey Aviation Ltd., and Mr. A. Vines, A.M.I.Prod.E., production manager of the Fairey Aviation Co. at Hayes, will present a joint Paper dealing with significant developments in production methods. They will refer to the new kinds of machine tools and other equipment which these new methods demand and will show how they enable production time to be reduced. The Paper will refer to the work which the Fairey Aviation Co. has done in the design and development of new machine tools for aircraft production.

Mr. I. R. Smith, chief inspector, Aircraft Division, Bristol Aeroplane Co. Ltd., will present a Paper on the control of production processes. Mr. Smith will deal with some of the ancillary production processes which sometimes cause considerable delays in production, and will review new techniques such as supersonic crack detection, and so on.

The Machine Tool Trades Association are sponsoring a Paper on the development of machine tools for aircraft production, which will be presented by Dr. D. A. Oliver, M.Sc., director of research, B.S.A. Group Research Centre.

BRITISH FIRM APPOINTED AS CONSULTANTS TO THE INDIAN GOVERNMENT

In the face of keen international competition, especially from America and Germany, a British firm, Associated Electrical Industries Ltd., has been appointed to act as consultants in a major project to create a heavy electrical manufacturing industry in India.

It is the intention of the Indian Government to build up an independent industry capable of meeting a substantial proportion of the country's requirements for hydro electric plant, electric traction equipment, generating plant and distribution gear.

A.E.I. has been appointed for a basic period of 15 years. The company will act as the Government's consultants in the design, layout and construction of the factory or factories, the general arrangements and procurement of plant, machines and equipment, and the preparation of a suitable training scheme. They will advise on all matters necessary for the successful working of the factory and will provide information regarding manufacturing techniques. They will supply designs for equipment and assist in the establishment of the engineering design department at the factory. A.E.I. will provide in India a resident engineer and the necessary technical specialists. A number of A.E.I. experts will be leaving for India shortly to survey suitable factory sites.

A factory of the size proposed is expected to employ about 10,000 people and the capital cost of such a factory is likely to be as much as £20 million.

Companies of A.E.I. have operated independently in India since the beginning of the century and in 1930 A.E.I. India, a subsidiary of the parent company in London, was formed. Nine years later a subsidiary manufacturing unit was established, which produces a wide range of light electrical equipment. The products of the new Indian Government plant will not conflict with those manufactured by the existing A.E.I. factory.

The present A.E.I. interests in India employ some 1,500 people. Many hundreds of Indian engineers have undergone their training at the factories of B.T.H. and M.-V. Companies in this country and many of them now hold posts of high responsibility in Indian industry. Although the new project provides for the establishment of an Apprentice Training Scheme in India, many more Indian nationals will undergo specialised training at the Works in England in the interim period.

NEW BTH COMPANY IN CANADA

Following the recent announcement that BTH is establishing a new company in Canada—The British Thomson-Houston Co. (Canada) Ltd., with headquarters in Toronto—we now learn that Mr. H. Gordon McHaffie, B.Sc., A.M.I.E.E., has been appointed director and general manager. The company also has a branch office in Montreal and in due course will open other offices in various parts of the Dominion.

The past achievements of BTH in the Dominion augur well for the future of the new company. Amongst large and important contracts carried out may be mentioned the two 25,000-kW, 60-cycle, double extraction turbo-alternators, one hydrogen-cooled, installed at Windsor, Ontario, for the Ford Motor Company of Canada; and the control equipment supplied for the Toronto Subway cars. More recently, orders were placed with BTH by British Columbia Electric Co. Ltd. for seven 230-kV, 750-MVA, oil circuit breakers, these equipments now being in course of manufacture at the London (Willesden) Switchgear Works.

ATOMS SHOW TO BE STAGED AT THE BIF

The "Atoms for Britain" exhibition, which created world-wide interest when originally staged at Geneva during the recent atom conference, will be seen for the first time in this country at next year's British Industries Fair.

It is to be presented by the U.K. Atomic Energy Authority and will be a major feature in the BIF electrical and electronics sections at Olympia, London, from April 23 to May 4.

The exhibition, which covers 7000 sq. ft., will show Britain's progress in harnessing nuclear power and in using atomic energy in industry, agriculture and medicine.

The research carried out at Harwell will be illustrated by large-scale models, photographs and diagrams. One of the models will be of DIDO, the "heavy-water" research reactor which will be completed by next summer.

A model of Britain's first atomic power station now being built at Calder Hall, Cumberland, will also be on show. This station, which is scheduled to start feeding electricity into the national grid at the end of next year, is the first of 12 to be built in Britain during the next 10 years. Another model on display will be of a more advanced and experimental type of power unit now under construction at Dounreay, Caithness.

Visitors will also see how radioactive isotopes can increase productivity and efficiency and save millions of pounds and thousands of working hours. It will be shown how isotopes can detect leaks in water mains and oil pipelines, trace the movement of river mud to aid dredging, develop better fertilizers and weed-killers and assist medical diagnosis, treatment and research.

The BIF will be held at Earls Court, London, from February 22 to March 2 and at Olympia, London, and Castle Bromwich, Birmingham, from April 23 to May 4.

G.E.C. ATOMIC ENERGY ACTIVITIES

The G.E.C.-Simon Carves Industrial Atomic Energy Group have come to an arrangement with The Motherwell Bridge & Engineering Co. Ltd. under which the latter company will be

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associated with them in the construction of nuclear power stations.

The works of The Motherwell Bridge & Engineering Co. Ltd. cover an area of 35 acres and have a shop floor area of 410,000 sq. ft. Outside of the shipbuilders the company is the largest buyer of steel plates in Great Britain. They have recently installed one of the largest stress relieving furnaces of its kind in the country and a pickling plant which contains the most modern equipment.

Associated with the development of their pressure vessel shops they have built modern laboratories for carrying out X-ray development and viewing, and mechanical and metallurgical testing covering all the modern methods of steel process control. As part of their current £1 million works extension and re-equipment scheme, they are installing a 2,000-ton hydraulic press for special plate work to supplement their existing 1000-ton press.

The company is closely associated with The Chicago Bridge & Iron Company of America, and a free interchange of technical developments and research takes place between the two companies. They are the sole licensees for Hortonspheres and they are at present constructing the 140-ft diameter sphere for the United Kingdom Atomic Energy Authority's experimental fast reactor at Dounreay, Caithness.

METROPOLITAN-VICKERS PROTON LINEAR ACCELERATORS FOR ATOMIC RESEARCH

In collaboration with the United Kingdom Atomic Energy Authority, a 0.5-50-MeV proton linear accelerator is being designed and manufactured by Metropolitan-Vickers Electrical Co. Ltd. for installation in the Atomic Energy Research Establishment at Harwell. This is the first section (described as the " pilot section " in the recently issued report of the U.K.A.E.A.) for a 600-MeV accelerator, but it is understood that a decision to proceed with the complete plant has not yet been made. Metropolitan-Vickers is also building an almost identical accelerator for the European Council for Nuclear Research (" CERN ") at Geneva.

The proton accelerator for Harwell will consist of three resonant cavities, respectively 20, 40 and 40 feet in length. The first 20 feet will accelerate protons from an injector to an energy of 10 MeV. Power is to be provided by triode amplifiers driven at a controlled frequency, special valves having been developed for this purpose by the U.K.A.E.A. Grid focusing will be employed in the first cavity, but the remainder of the machine will use magnetic alternating-gradient focusing in order to extract a higher current beam. In this method of focusing a quadripolar lens is included inside each drift tube, and these lenses are arranged so that the focusing in one plane and de-focusing in a plane at right angles are interchanged on alternate drift tubes; this produces an overall focusing in the manner now employed for large synchrotrons.

For the Harwell equipment, which will produce protons at an energy of 50 MeV, radio-frequency power will be supplied to each cavity in pulses of 400 microseconds duration at a maximum recurrence rate of 50 per second; the injector is to supply a peak current of 5 mA at 0.5 MeV, and, as 0.5 mA is expected to be trapped in phase and accelerated within the machine, a high output current may be expected. The equipment for Geneva will operate at a much lower duty cycle, as it is to be used as an injector for the new 25-GeV proton synchrotron to be built there.

CONTRACTS

BRITISH RAILWAYS DIESEL LOCOMOTIVE ORDERS

Ten main-line mixed traffic and ten branch line diesel-electric locomotives will be built by the **North British Locomotive Co. Ltd.** for the first stage of the motive power programme in the British Railways £1200 million modernization plan. Both types will be four-axle, double-bogie locomotives with electrical equipments supplied by **The General Electric Co. Ltd.**

For the main-line locomotives, the power equipment will comprise a pressure-charged vee 12-cylinder N.B.L./M.A.N. 1000 hp, 1500 rpm engine direct-coupled to a G.E.C. main generator with overhung auxiliary generator. Each axle will be driven through Wiseman resilient gears by a nose-suspended, forced-ventilated traction motor. Control will be by a combination of generator field control and variation of engine speed, the latter being effected by three air-operated pistons acting through levers on the engine governor to provide eight engine speed steps. Automatic torque control through an oil servo regulator will be available on all controller notches. These locomotives are designed for a maximum axle-loading of 18 tons and a top speed of 75 mph. There will be a driving cab at each end of the locomotive.

The branch-line locomotives will be of similar wheel arrangement to the main-line design, but will have a driving cab at one end only, with duplicated controls for driving from either side. They will be powered by a 16-cylinder Paxman YHXL 800 hp, 1250 rpm engine direct-coupled to a flange-mounted G.E.C. main generator with overhung auxiliary generator. Forced-ventilated, nose-suspended traction motors will drive the axles through Wiseman resilient gears. The control system will be generally similar to that of the main-line locomotives. In the branch line design the axle load will be 17 tons and the maximum speed 60 mph. Both types will be arranged for multiple-unit working.

The British Transport Commission—as already announced—has placed a contract for forty main-line diesel-electric locomotives with **The English Electric Company Limited,** the only British manufacturer capable of building complete diesel-electric and straight-electric locomotives in its own works. Its designs incorporate " English Electric " diesel engines, generators, motors and mechanical parts.

The first main-line diesel-electric locomotives to enter service in Great Britain, in Australia and in New Zealand—to quote a few examples—were all powered by " English Electric " equipment.

The company supplied the diesel-electric equipment for the five locomotives 10 000, 10 001, 10 201, 10 202 and 10 203, the latter being the most powerful diesel-electric locomotive operating on British Railways until the arrival of the " English Electric " 3300 hp " Deltic " locomotive last month.

On the Southern Region of British Railways, well over one thousand motor coaches are equipped with " English Electric " straight-electric traction motors and control equipment. This Region has the most intensive suburban service in the world and is also one of the most successful electrified systems in the world.

" English Electric " activities in the field of straight-electric traction are world-wide, their electric locomotives being in service in North and South America, South Africa, India, Australia, New Zealand, Spain and other countries.

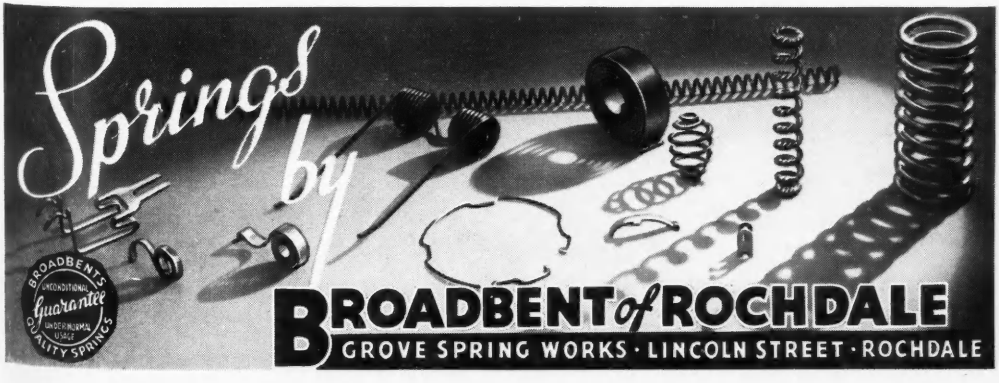
Twenty of the locomotives on this new contract will be of the 1000 hp double bogie (Bo-Bo) type. The " English Electric " 8 SVT design of diesel engine will be applied. These locomotives have been designated type "A" by British Railways.

Another ten of the locomotives ordered will be of the 1100 hp double bogie (Bo-Bo) type. These have been designated type " B " by British Railways. A 9-cylinder super-charged Napier Deltic engine will be installed. It is interesting to note that the world's most revolutionary motive power unit—the 3300 hp Deltic locomotive—which has been undergoing preliminary trials on British Railways for the past month, employs two 18-cylinder Napier Deltic engines.

The remaining ten locomotives will be of the 2000 hp double bogie (1Co-Col) type and will incorporate the 16 SVT type " English Electric " diesel engine. These locomotives have been designated type " C " by British Railways. They will follow closely British Railways designs, incorporating " English Electric " equipment, already in service for some years on both the London Midland Region and the Southern Region of British Railways. These locomotives have operated fast London-to-Glasgow express train services and have hauled such famous trains as " The Atlantic Coast Express " and " The Golden Arrow ".

Crompton Parkinson Ltd. are to be entrusted with the supply of traction electrical equipment for 30 main line locomotives for British Railways.

Ten of these are of the largest capacity for use with the highest powered (2300 hp) diesel engines to go into service on British Railways. These are for heavy duty locomotives. 20 sets will be of medium capacity for use with 1160 hp engines in mixed traffic locomotives.



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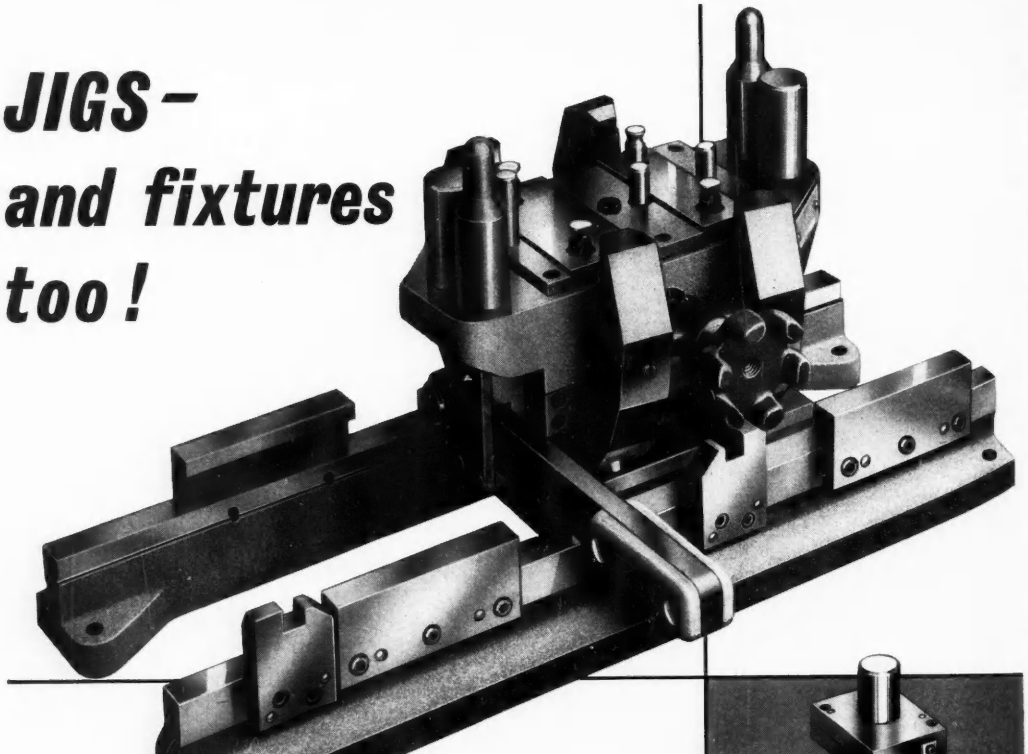

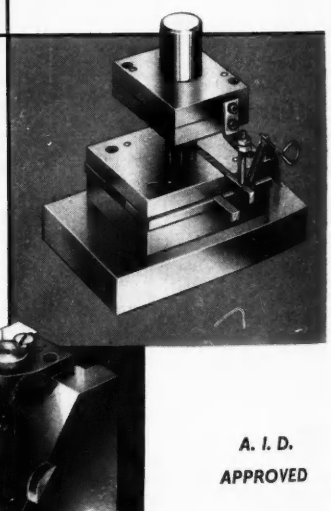

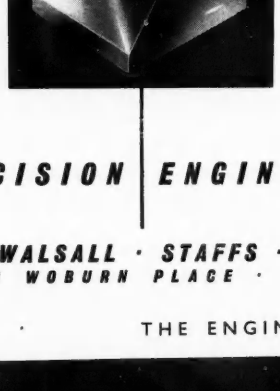

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The majority of the locomotives ordered for this new Railway programme will be built by British locomotives building firms and these 20 mixed traffic locos with Crompton Parkinson equipment will be built by The Birmingham Railway Carriage & Wagon Co. Ltd. However, British Railways have themselves decided to build their first diesel electric locomotives of over 2000 hp and Crompton Parkinson will be the only firm to supply electrical equipment for these Railway-built locos in the highest capacity class.

Each of the 30 equipments includes a main and auxiliary generator; four or six traction motors for mixed traffic and heavy duty locos respectively; four or five auxiliary machines for driving compressors, exhausters, fans, pumps, etc., together with the electric control equipment necessary for the correct and safe functioning of the whole under the control of the driver.

All the generators and motors on these orders will be manufactured in Crompton Parkinson's Chelmsford Works, while the control gear will be built to Crompton Parkinson's requirements by Allen West & Co. Ltd.

Delivery of these orders, which are among the largest for electrical equipment placed by British Railways in this new programme, will extend into the early part of 1958. Their value is approximately £$\frac{3}{4}$ million.

Brush Bagnall Traction Ltd., of Loughborough, a member of The Brush Group, have received an order for twenty diesel electric locomotives for the British Transport Commission. The order is worth nearly £1$\frac{1}{2}$m.

The first locomotive will be ready for service in 21 months' time, and one locomotive will be delivered every three weeks thereafter.

The order is part of an initial project for purchasing 130 locomotives, and it is understood that the locomotives in this pilot order will be subject to extensive tests to determine the best types.

British Railways modernization programme, as announced, involves the purchase of 2500 diesel electric locomotives and the ultimate placing of larger contracts will depend upon the result of these tests.

With a fuel capacity of 500 gallons, which is sufficient for approximately 500 miles, the Brush Bagnall locomotives are designed for a maximum safe speed of 75 miles per hour. They will be used for passenger and freight services and will be able to maintain high average speeds.

Included in the equipment is a train heating boiler which provides steam for the heating of the coaches. The water supply for this purpose is carried in tanks mounted on the locomotive.

The locomotives are designated Type AIA-AIA, which means that the superstructure is mounted on two bogies, each bogie having three axles of which the two outer axles are motored, the centre axle being used for carrying purposes only.

The locomotives are provided with a driving cab at each end, and there is provision for connecting gangways which will be used when the locomotives are coupled together for multiple working.

In appearance, the locomotives are similar to the twenty-five 1000 hp locomotives which Brush Bagnall have built for the Ceylon Government Railway.

Each of the two bogies has six wheels with a wheelbase of 14 ft. The overall length of each locomotive is 57 ft and in working order it weighs 104 tons.

The power unit consists of the Mirrlees vee-form 12-cylinder turbo-charged, four-stroke oil engine developing 1250 hp at 850 rpm, coupled to a Brush generator with a continuous output of 828 kW. An auxiliary generator is flange-mounted on the main generator and the output from this is used to drive the air brake compressor and the vacuum compressors. Engines and electrical equipment of this type have already had considerable service in Ceylon.

In the preliminary tests, to be carried out by British Railways, particular attention will be paid to the performance of the diesel engines, and in this respect ease of maintenance will be most important.

The locomotives were designed by Brush Bagnall Traction Ltd. to the requirements of the British Transport Commission. The traction motors, control gear, main generators and superstructure will be manufactured by Brush Electrical Engineering Co. Ltd., Loughborough, and the diesel engines by Mirrlees, Bickerton and Day Ltd., Stockport (another manufacturing subsidiary of The Brush Group Ltd.). The complete locomotives will be assembled in the Brush Bagnall Locomotive Erecting Shop at Loughborough.

The United States Army Corps of Engineers has awarded a contract for the manufacture and delivery of one 90,750/121,000 kVA 13.2/161 kV three-phase, 60 cycles power transformer, together with all accessories and spare parts, to **English Electric Export and Trading Company Limited.** It will be recalled that earlier this year English Electric Export and Trading Company Limited were the lowest bidder against the first invitation for this same contract, but all bids were cancelled and the invitation re-issued.

The transformer will be installed in the switchyard at Table Rock Dam, located on the White River in Taney County, South West Missouri, and will serve two generators each rated at 52,632 kVA. In November of last year "English Electric" were awarded the contract for the two 68,000 hp vertical Francis water turbines for this project.

The present transformer for Table Rock Dam will be of the two-winding, oil-immersed, self-cooled, forced air-cooled, Class OA/FA, dual-rated, inert gas-filled, three-phase type, suitable for outdoor operation.

Other transformer orders from the U.S.A. include those for the St. Lawrence Power Project—120 MVA, 230 kV; City of Seattle—125 MVA, 230 kV; Chief Joseph Dam—310 MVA, 230 kV; Bonneville Power Administration—250 MVA, 254 kV, and the Folsom Dam in California—80 MVA, 230 kV.

The Nova Scotia Light & Power Company have placed a second order with the **English Electric Company Limited** for a 45,000 kW, 3,600 rpm steam turbo-alternator set, complete with feed heating and condensing plant, for installation at their Water Street Power Station in Halifax, Nova Scotia.

The value of the order is approximately £450,000. The first set was ordered in July 1954. The second set, like the first, will be built at the company's Rugby Works.

The turbine is designed to operate with steam at 900 psig, 900°F, at the turbine stop valve and for five-stage feed heating with a vacuum of 28$\frac{1}{2}$ in. at M.C.R.

The alternator is of the hydrogen-cooled type for generation at 13,200 volts, three-phase, 60 cycles. The condensing plant is of the cleanable twin shell type and the five-stage feed heating scheme will comprise three low-pressure and two high-pressure feed water heaters.

An order totalling more than a million dollars to supply diesel engines for a Canadian tractor has been secured by **F. Perkins Ltd.**, of Peterborough.

The company recently negotiated a £1,000,000 order for tractor engines with Yugoslavia.

The new order has been placed by the Cockshutt Farm Equipment Ltd., of Brantford, Ontario. It is the first time that a Canadian tractor firm has standardized on a British engine.

The order is for the Perkins L4 engine, claimed to be the cheapest of its horsepower in the world. It is being installed in the Cockshutt "40 PD" 3-4 plough, 4-wheel tractor.

Leyland Motors Ltd., Leyland, Lancashire, has received a contract from the Ministry of Communications of the State of Israel for 250 omnibus chassis estimated to cost £1,000,000. The vehicles are Leyland Royal Tiger Worldmaster models with 150 hp underfloor diesel engines.

R. H. Neal & Co. Ltd., Plant House, Ealing, London, W.5, has received two contracts for mobile cranes from the Egyptian Republic Railways and the Persian Customs Department, respectively. The value of the contracts is in excess of £120,000.

The Shaw Savill Line has placed orders for two refrigerated motorships for its cargo services to Australia and New Zealand with Camel Laird & Co. (Shipbuilders and Engineers) Ltd. and Vickers-Armstrongs (Shipbuilders) Ltd., Newcastle-upon-Tyne, respectively.

The ships will have an overall length of 512 ft, a moulded breadth of 70 ft, a loaded draught of 30 ft 4$\frac{1}{2}$ in, and a gross tonnage of about 11,500 tons. There will be 375,000 cubic feet for refrigerated cargo and 250,000 cubic feet for general cargo. Each ship will be driven by an eight-cylinder supercharged opposed piston diesel engine constructed by Harland & Wolff Ltd. The service speed of the ships will be 17 knots.

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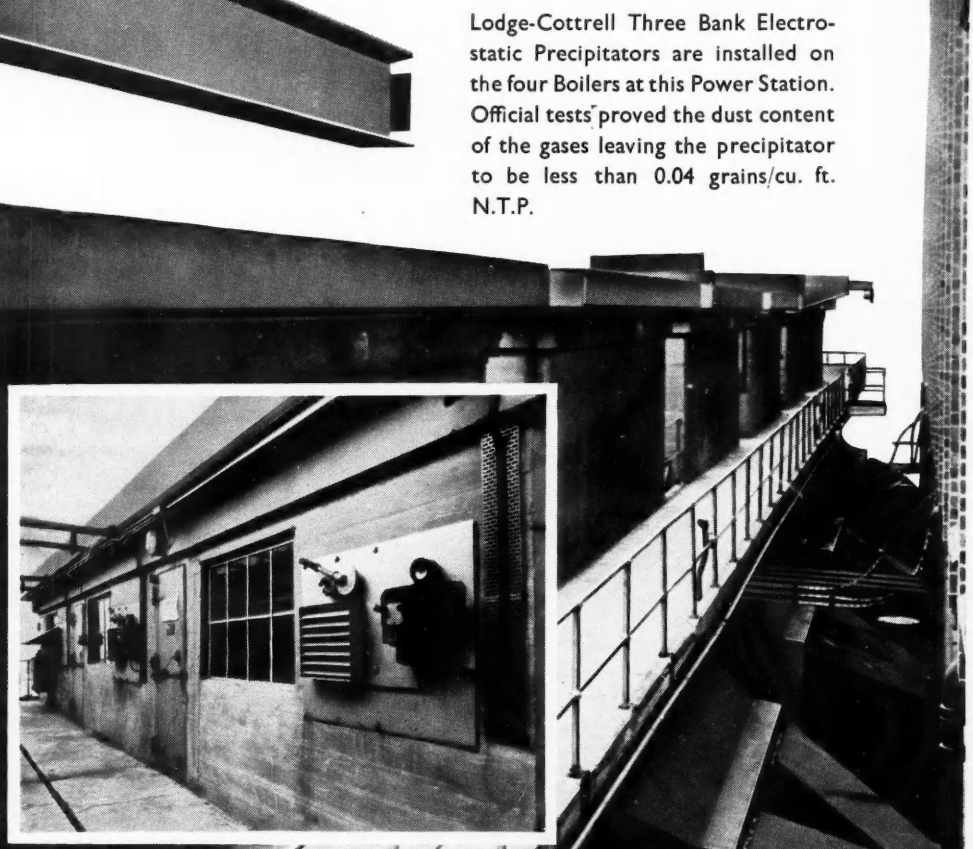

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Virtually all the £9 million worth of British electrical equipment sold to Canada each year (with the exception of some heavy plant for power stations) now receives a seal of approval before it leaves this country. Approval is given by the British Standards Institution, acting as agent for the Canadian Standards Association. It means that such equipment goes straight into service without the risk of being returned to Britain for costly alterations. This system of approval-in-advance is now successfully used by some 400 British firms making products from electrically-operated machine tools to electric kettles. Very many thousands of separate products have already been approved.

To further strengthen the approvals service the British Standards Institution has now published a completely new and greatly enlarged edition of its booklet, "The Canadian Standards Association—Information for U.K. Manufacturers Exporting Electrically-Operated Equipment to Canada."

Among the important alterations and additions which have been made in the new edition are the following :

A paragraph has been included concerning the approval of equipment incorporating pressure vessels—for example, motor-operated garage compressors. It points out that there are special Canadian requirements for the certification of pressure vessels having capacities in excess of certain minimum sizes and worked at certain defined pressures. (A B.S.I. leaflet on exports of boilers and pressure vessels is now being prepared.) Another new section describes the availability of a consultative service in Canada concerned with exports of special kinds of wire and cable not subject to approval in the usual way.

The appendix listing the Canadian Approval Specifications has been brought up-to-date, as has the appendix giving the names and addresses of the Provincial Chief Electrical Inspectors in Canada. Details of related B.S.I. publications are included for the first time.

More detailed information is given on approval of flameproof equipment and on the approval and acceptance of high rupturing fuses. Material is included regarding the approval of stator-rotor units; and the information on the type of service applicable to wires and cables has been amplified and brought up-to-date. Price 5/-.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London, W.1)

Glossary of terms relating to automatic digital computers • B.S.2641 : 1955 contains about one hundred entries, covering the following subjects :—

Fundamental terms
Coding systems
Storage techniques (mainly electronic)
Programming and routines

For completeness, a few definitions relating to number representation and number scales are included. Price 3/-.

EXHIBITIONS

Australian World's Fair.—Thurs., July 26, to Sat., Aug. 4, 1956, at Sydney. Apply to the managing director, Australian World's Fair, 234 Clarence-street, Sydney, N.S.W., Australia.

Copenhagen International Fairs.—*Technical:* Fri., Mar. 16, to Sun., Mar. 25, 1956. *Trade:* Fri., April 6, to Sun., April 15, 1956. Apply to the offices, Forchhammersvej 13, Copenhagen V.

American Society of Tool Engineers Exhibition.—Mon., Mar. 19, to Fri., Mar. 23, 1956, in the International Amphitheatre, Chicago. Apply to the American Society of Tool Engineers, 10700 Pitan-avenue, Detroit 21, Mich., U.S.A.

Electrical Engineers (A.S.E.E.) Exhibition, Fifth.—Tues., Mar. 20, to Sat., Mar. 24, 1956, at Earl's Court, London, S.W.5. Organized by Electrical Engineers (ASEE) Ltd., 23 Bloomsbury-square, London, W.C.1. Tel. MUSeum 3450.

British Industries Fair.—Wed., Feb. 22, to Fri., Mar. 2, 1956 (including British Toy Fair), at Earl's Court, London, S.W.5. (Organized jointly with British Toy Manufacturers Association.) Also Mon., April 23, to Fri., May 4, 1956, at Olympia, London, W.14, and at Castle Bromwich, Birmingham. Apply to British Industries Fair, Ltd., 9 Kingsway, London, W.C.2. Tel. COVent Garden 1461; or to general manager, B.I.F., 95 New-street, Birmingham, 2. Tel. Midland 5021.

Machine Tool Exhibition, International.—Fri., June 22, to Fri., July 6, 1956, at Olympia, London, W.14. Organized by the Machine Tool Trades Association, Victoria House, Southampton-row, London, W.C.1. Tel. HOLborn 4667.

Trieste International Trade Fair, Eighth.—Sun., June 24, to Sun., July 8, 1956, at Trieste. *Agents:* Italian Chamber of Commerce for Great Britain and British Commonwealth, 652 Grand Buildings, Trafalgar-square, London, W.C.2. Tel. WHItehall 5521.

Japan International Trade Fair.—Sun., April 8, to Sun., April 22, 1956, at Osaka. Organized by the Japan International Trade Fair Commission, Honmachibashi, Higashi-Ku, Osaka, Japan.

Factory Equipment Exhibition, Fourth.—Mon., April 9, to Sat., April 14, 1956, at Earl's Court, London, S.W.5. Apply to Mr. J. E. Holdsworth, 4 Snow-hill, Holborn-viaduct, London, E.C.1. Tel. CENtral 0354.

Radio and Electronic Components.—Tues., April 10, to Thurs., April 12, 1956, at Grosvenor House, Park-lane, London, W.1. Pre-view for overseas and special guests, Mon., April 9. Annual private exhibition organized by the Radio and Electronic Component Manufacturers' Federation, 21 Tothill-street, London, S.W.1. Applications for admission must be made in advance.

Production Exhibition.—Wed., May 23, to Thurs., May 31, 1956, at Olympia, London, W.14. Organized by Andry Montgomery Ltd., 11 Avenue Chambers, 4 Vernon-place, London, W.C.1. Tel. CHAncery 2223.

Mechanical Handling Exhibition, Fifth.—Wed., May 9, to Sat., May 19, 1956, at Earl's Court, London, S.W.5. Organized by *Mechanical Handling*, Dorset House, Stamford-street, London, S.E.1. Tel. WATerloo 3333.

Physical Society's Exhibition of Scientific Instruments and Apparatus.—Mon., May 14, to Thurs., May 17, 1956, at the Royal Horticultural Society's Old and New Halls, Vincent-square and Greycoat-street, London, S.W.1. Organized by the Physical Society, 1 Lowther-gardens, Prince Consort-road, London, S.W.7. Tel. KENsington 0048.

The October issue of **The Nickel Bulletin** includes a series of interesting items on cast iron, covering thermal-shock resistance, the properties of low-expansion nickel-alloy irons and oxidation-resistance of high-alloy types.

In connection with high-temperature materials attention is directed to the announcement of a new number of the Nimonic series, Nimonic 100, which can be used at temperatures higher than those permissible for any other alloy of the group. Among abstracts relating to gas-turbine materials is a study of the relation between static and fatigue properties at elevated temperatures, and a report on the influence of vanadium pentoxide on the scaling of alloys at high temperatures.

References to stainless steels in chemical engineering include applications in pickling equipment, dyeing plant, pulp-bleaching equipment and other branches of the process industries. The increasing importance of such materials in structural engineering is demonstrated by a report on fundamental research which is in progress as a basis for formulating a design specification for the hardenable 17-7 chromium-nickel grade.

Copies of *The Nickel Bulletin* are obtainable free of charge from : The Mond Nickel Co. Ltd., Publicity Department, Thames House, Millbank, London, S.W.1.

Classified Advertisements

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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BOOKS RECEIVED

British Standards Institution Annual Report, 1954-5. 243 pp. Publishers: British Standards Institution, 2 Park Street, London, W.1. Price :—5/-.

A very wide range of activity now embraced by the British Standards Institution is reviewed in this Annual Report for the year ending on March 31, 1955. The introductory General Report refers to Codes of Practice and Consumer Goods, while a new section of the Divisional Reports is devoted to the work of the Council for Codes of Practice, which has now been in action for over a year.

The largest section of the Report is naturally concerned with the projects for British Standards which have been under consideration during the year by some sixty major industries. This section includes notes on some of the more important standards issued during the year and on significant developments which have taken place on other projects. In this section can be found, under the B.S.I. network of committees, projects for a wide range of items, from parking lights to crash-helmets, as well as many others which are integral to a comprehensive variety of products or processes.

A page of statistics, included in the General Report, serves to indicate at a glance the continuing scale of B.S.I. activity—just under 900,000 copies of standards sold during the year, over 4000 meetings of committees held, and 1300 licences to use the B.S. Certification marks issued. The number of subscribing members of the Institution is now 8300, drawn from commercial firms, trade associations, and professional bodies.

Law and the Engineer. By Christopher F. Mayson, A.M.I.E.E. 490 pp. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price :—63/-.

As Sir Alfred Denning so aptly puts it in his foreword to this interesting volume, " I expect that many an engineer can get along very well without knowing anything about the law; but I can't help thinking that he would get along a good deal better if he had some knowledge of it . . ." The aim of this book, then, is to present to engineers, in a practical and understandable manner, those aspects of English law which are likely to be of interest and concern to them. Mechanical and electrical engineers have been kept particularly in mind, because builders, architects, and civil engineers have, to a large extent, been catered for. The book should also appeal to the more advanced engineering student, for it is well established that a knowledge of law is an essential part of the broader type of education which the present-day professional engineer requires, if he is to qualify himself for the higher administrative posts.

The author has endeavoured to steer a middle course between the complete *vade-mecum* and the digested summary, and to give engineers a knowledge of basic principles combined with enough practical application to enable them to recognize when it would be wise to take expert legal advice. The law dealt with is the civil, as opposed to the criminal; in other words, it is concerned more with the rights and obligations of individuals *vis-à-vis* each other than with those delinquencies which attract the attention of the police and occupy the time of the Criminal Courts. Those branches of the civil law about which the engineer needs to have some working knowledge include the law of contract in most of its aspects, the law relating to negligence and nuisance, the law relating to employment, and the safety rules laid down by such enactments as the Factories Acts.

This excellent work, which is very carefully referenced and also contains a glossary of legal terms, a bibliography, and a comprehensive index, should prove invaluable to the engineer.

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5. Cutting and Metal-Working Oils. The subject of cutting and metal-working oils is dealt with comprehensively in an extremely well-produced and illustrated 80-page book. After a brief historical survey of metal working and cutting, it appraises the fundamentals of these processes, and describes the functions of cutting fluids, together with the relation between the properties of fluids and the various types of cutting operation. Other chapters are devoted to the machining of special materials, ranging from malleable cast iron to glass, and to cold-working lubricants and heat-treatment oils.

As is only to be expected in a publication emanating from a company which has specialized in industrial oils, the book contains a wealth of useful information, clearly and authoritatively expressed.

6. Ash-Handling Plant. Details are contained in a neatly produced and illustrated 16-page brochure of complete plant for the handling of ash dust and grits from boiler plants.

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7. Counting Instruments. Attractively presented in a neat folder, a series of leaflets describes and illustrates a comprehensive range of mechanical and electromagnetic counting instruments, including medium-size counters, small stroke counters, small non-reset counters, and meter accessories, such as number wheels and pinions, in tin and plastic.

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8. Axial-Flow Fans. The new 56-page edition of a publication issued by a firm of specialists in fan manufacture and design provides striking evidence of the advances made in the manufacture of axial-flow fans. This interesting and beautifully illustrated publication presents fans, with alternatives in most cases, for over 1100 different volume/pressure combinations, from 1000 to 55,000 cfm, and from free air to 20 in. water-gauge. Included are selection tables, containing over 2200 entries, each with full performance data. Alternative motors are listed for single- and three-phase, and for flameproof duties, while specially treated motors are described for high ambient temperatures up to 300° F and for moisture-laden atmospheres.

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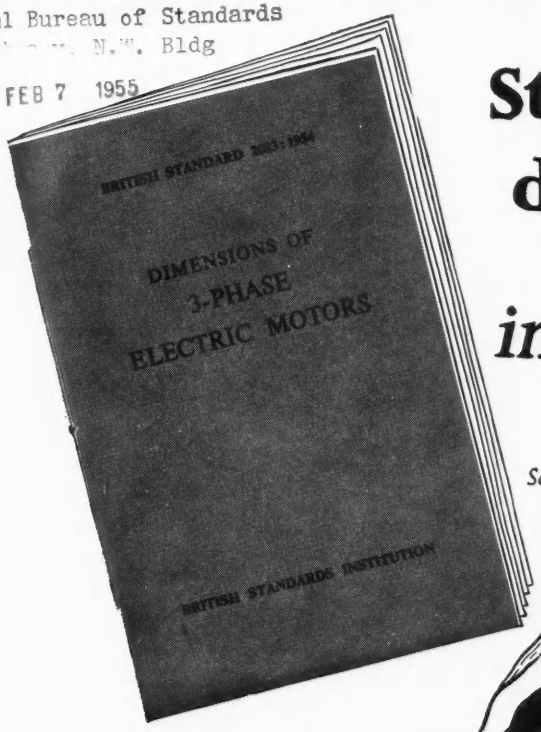

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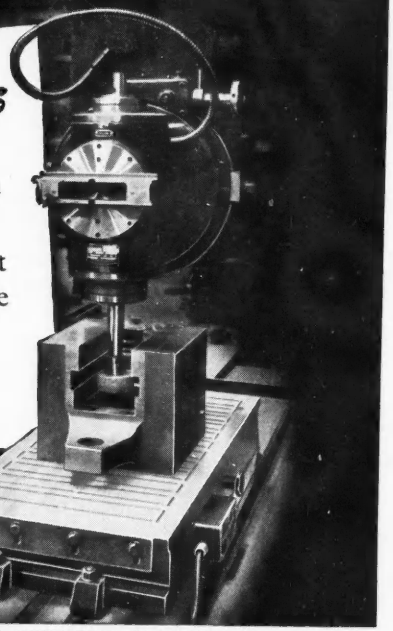

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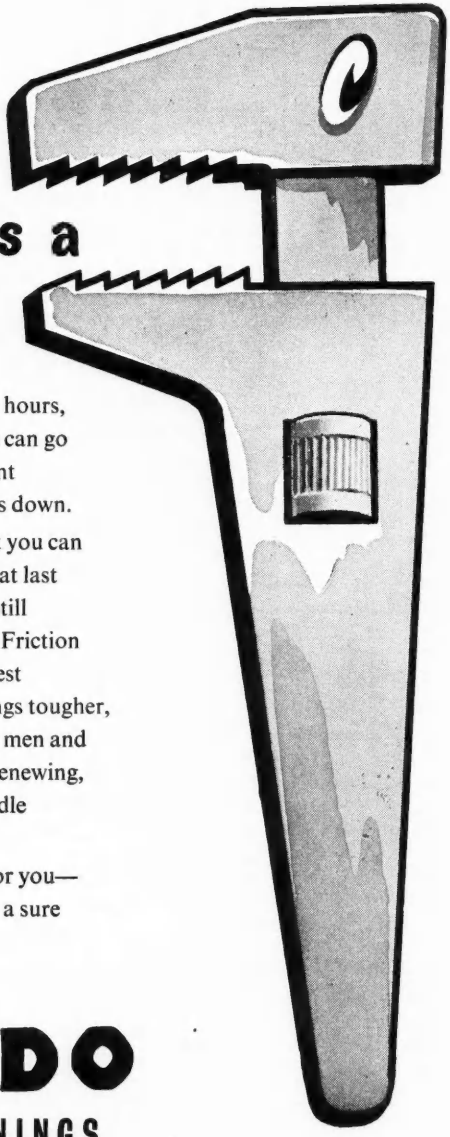

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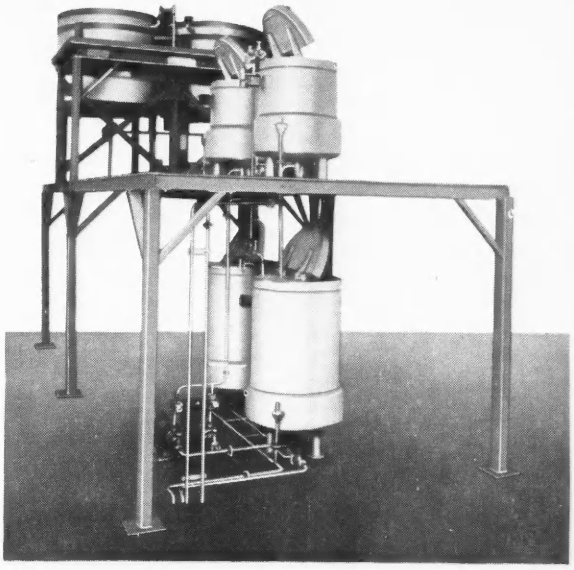

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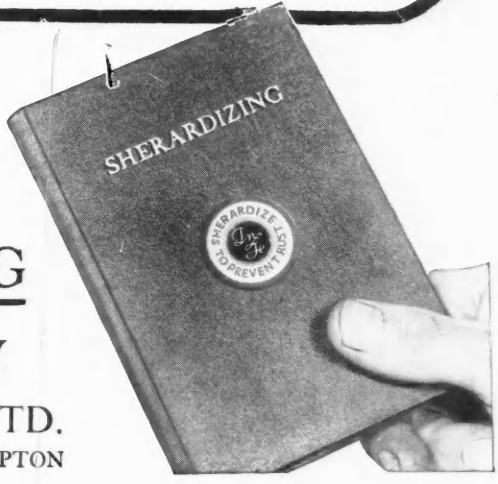

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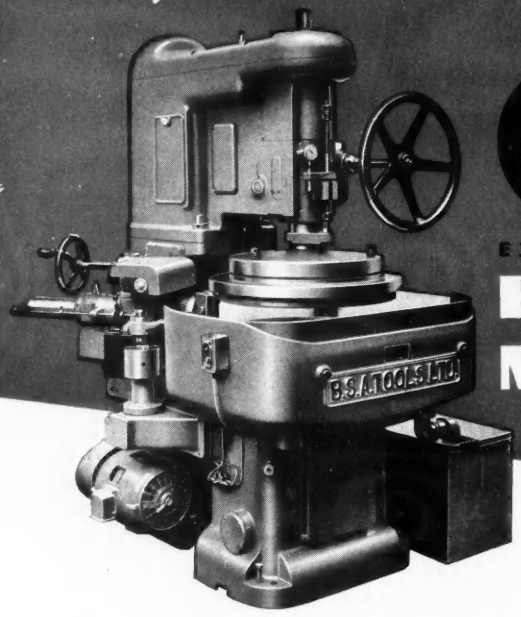

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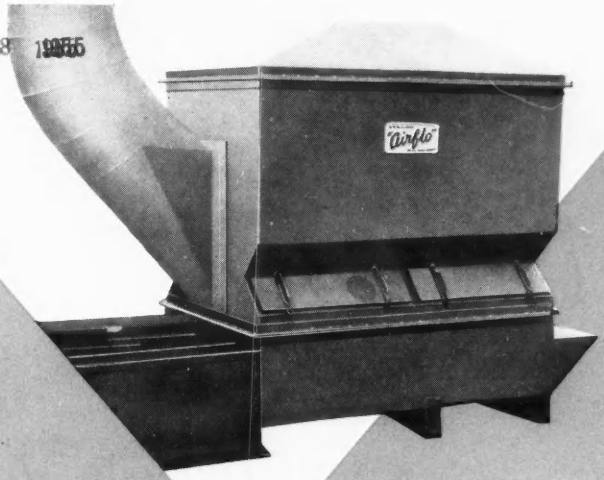

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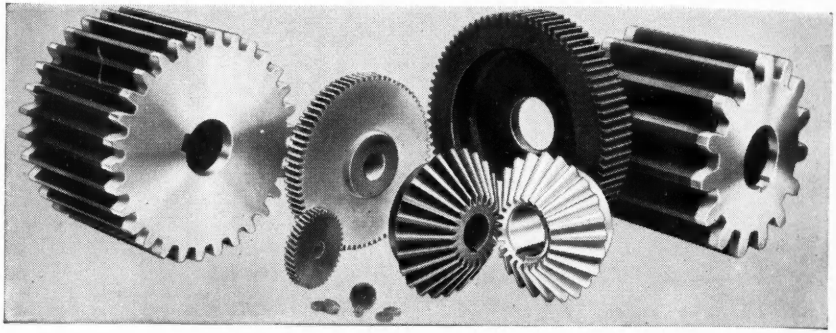

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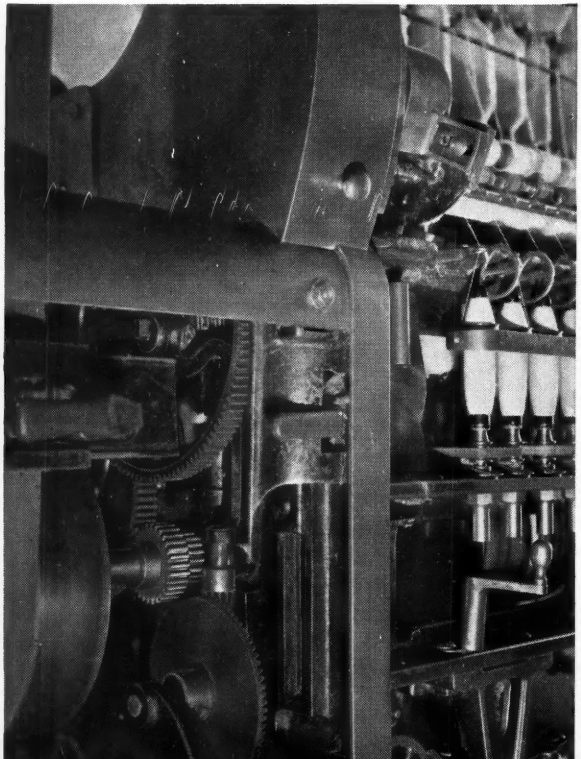

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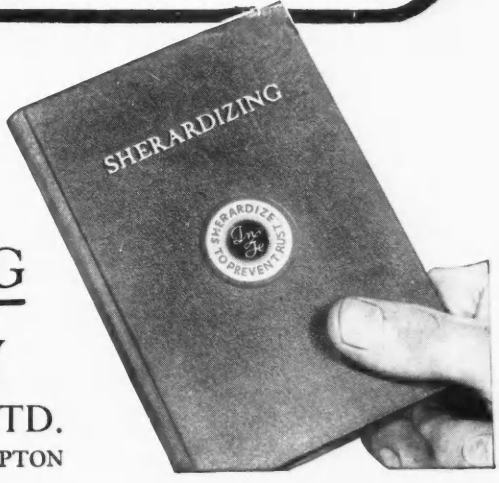

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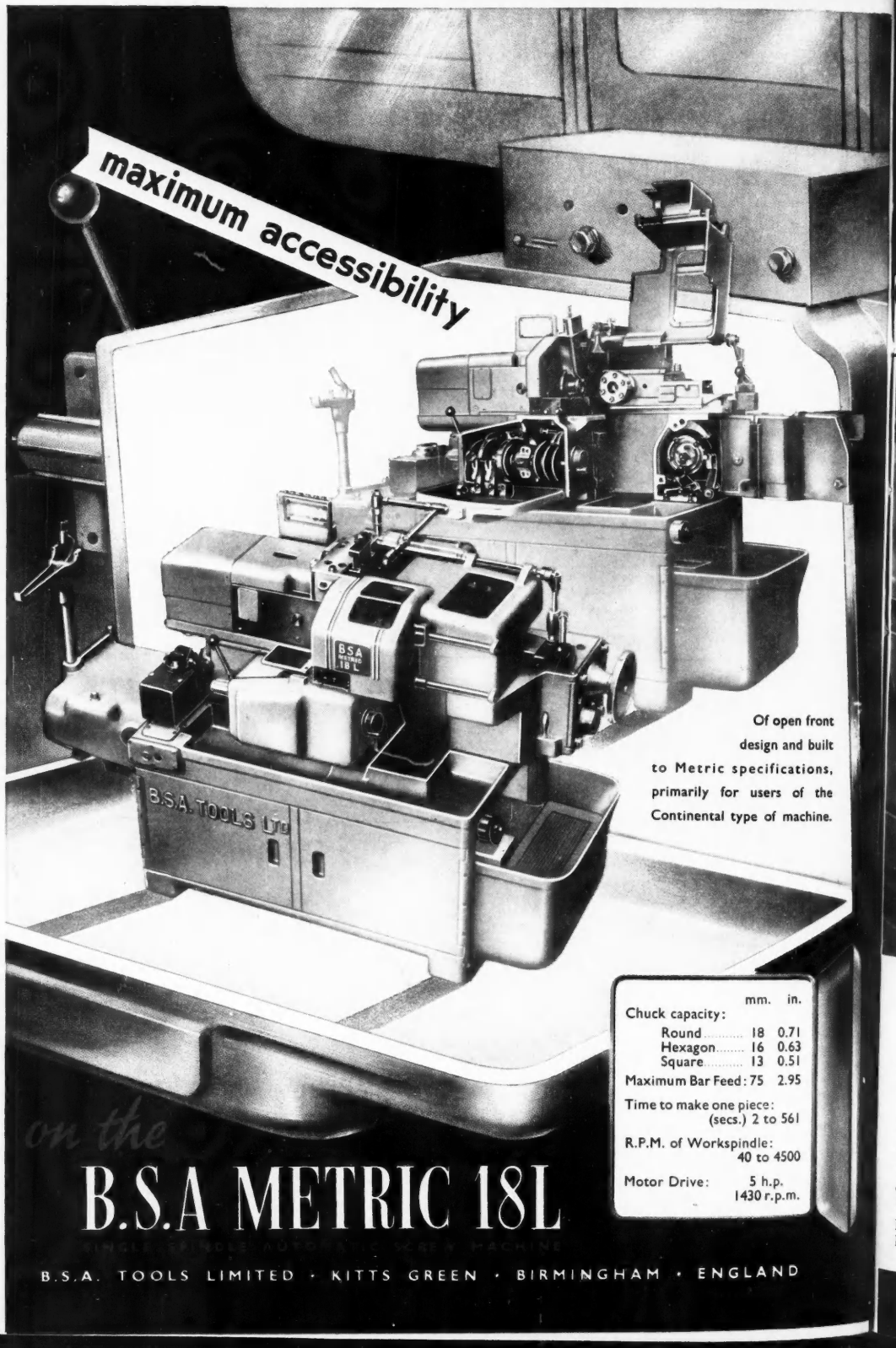

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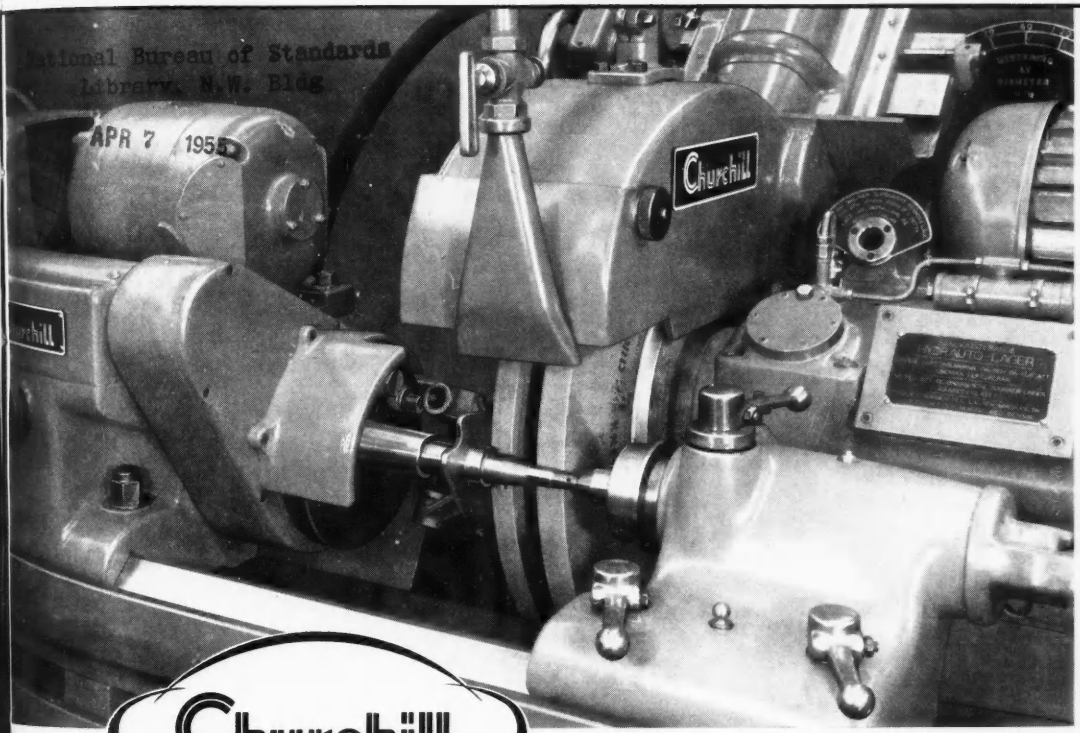

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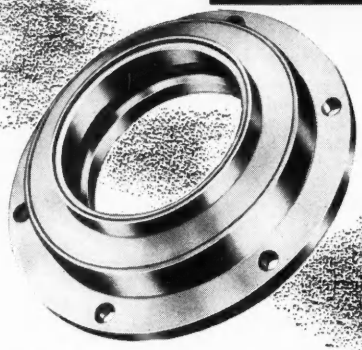

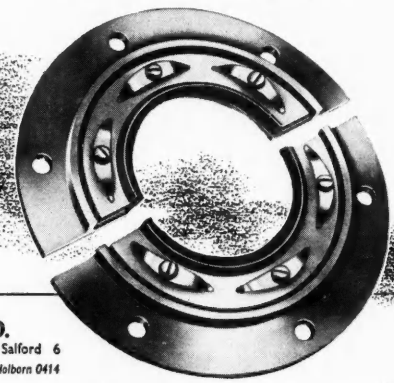

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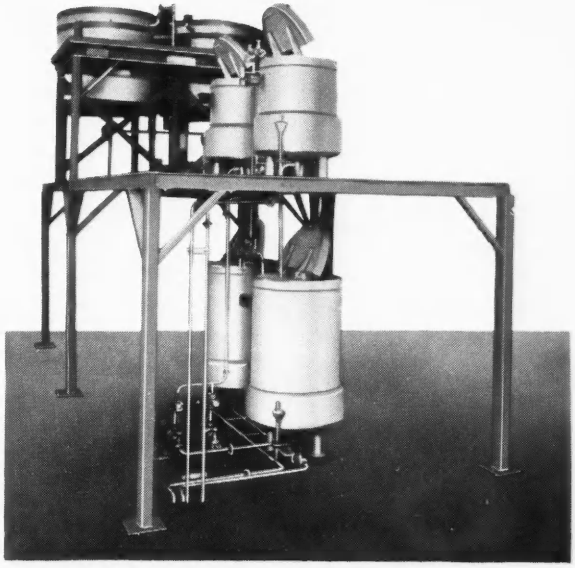

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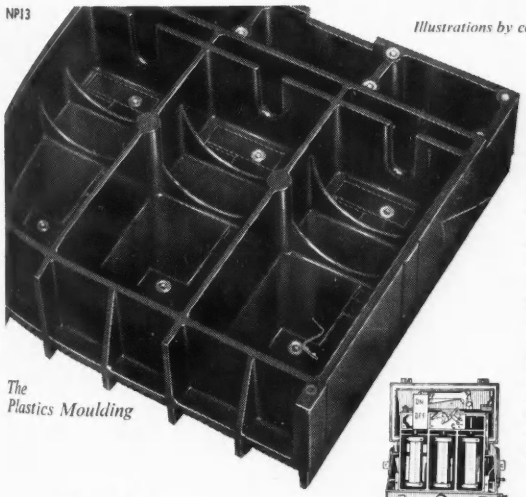

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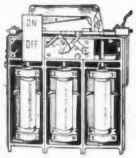

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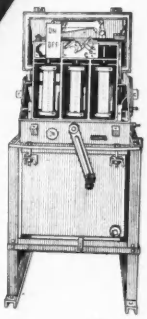

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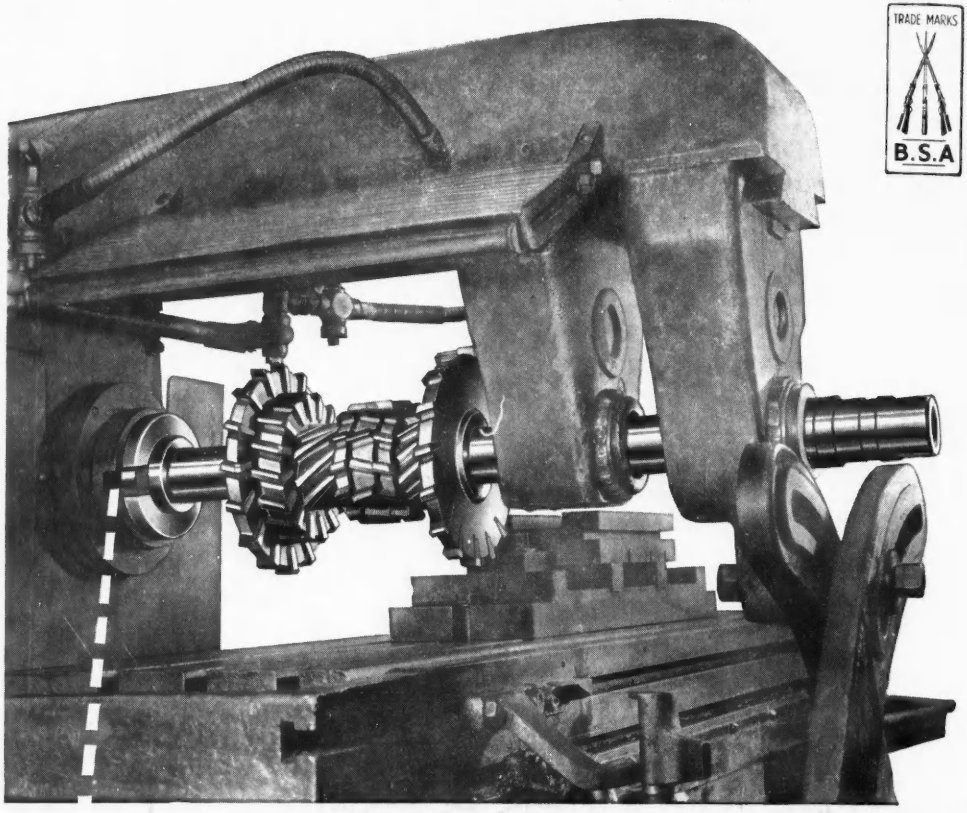

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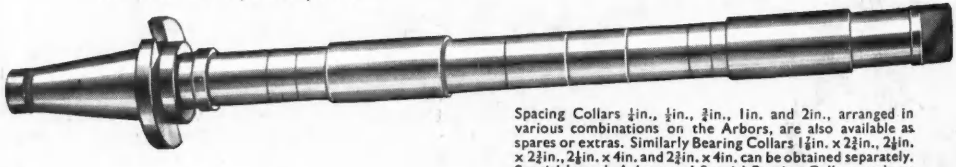

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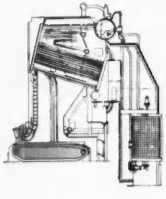

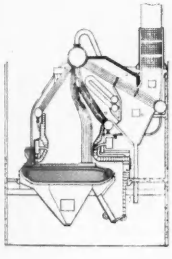

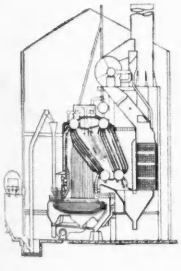

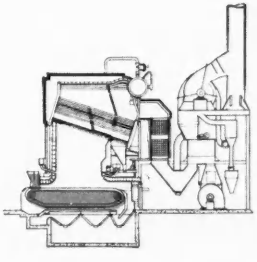

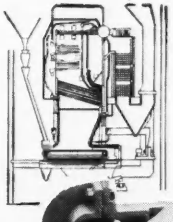

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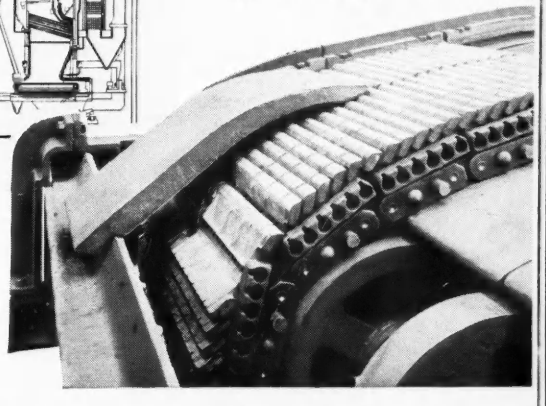

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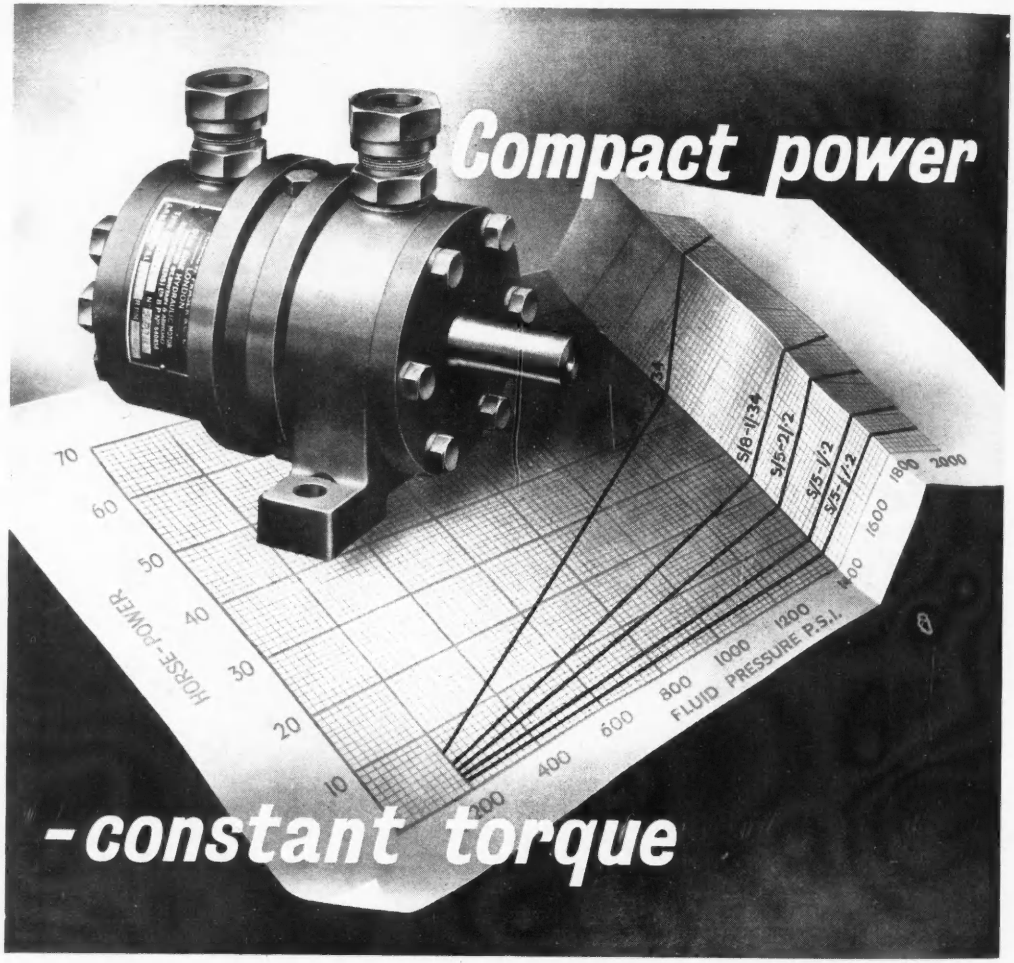

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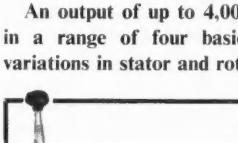

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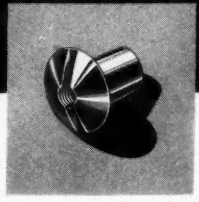

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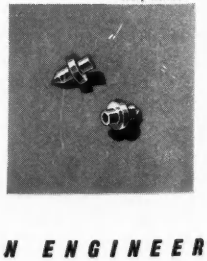

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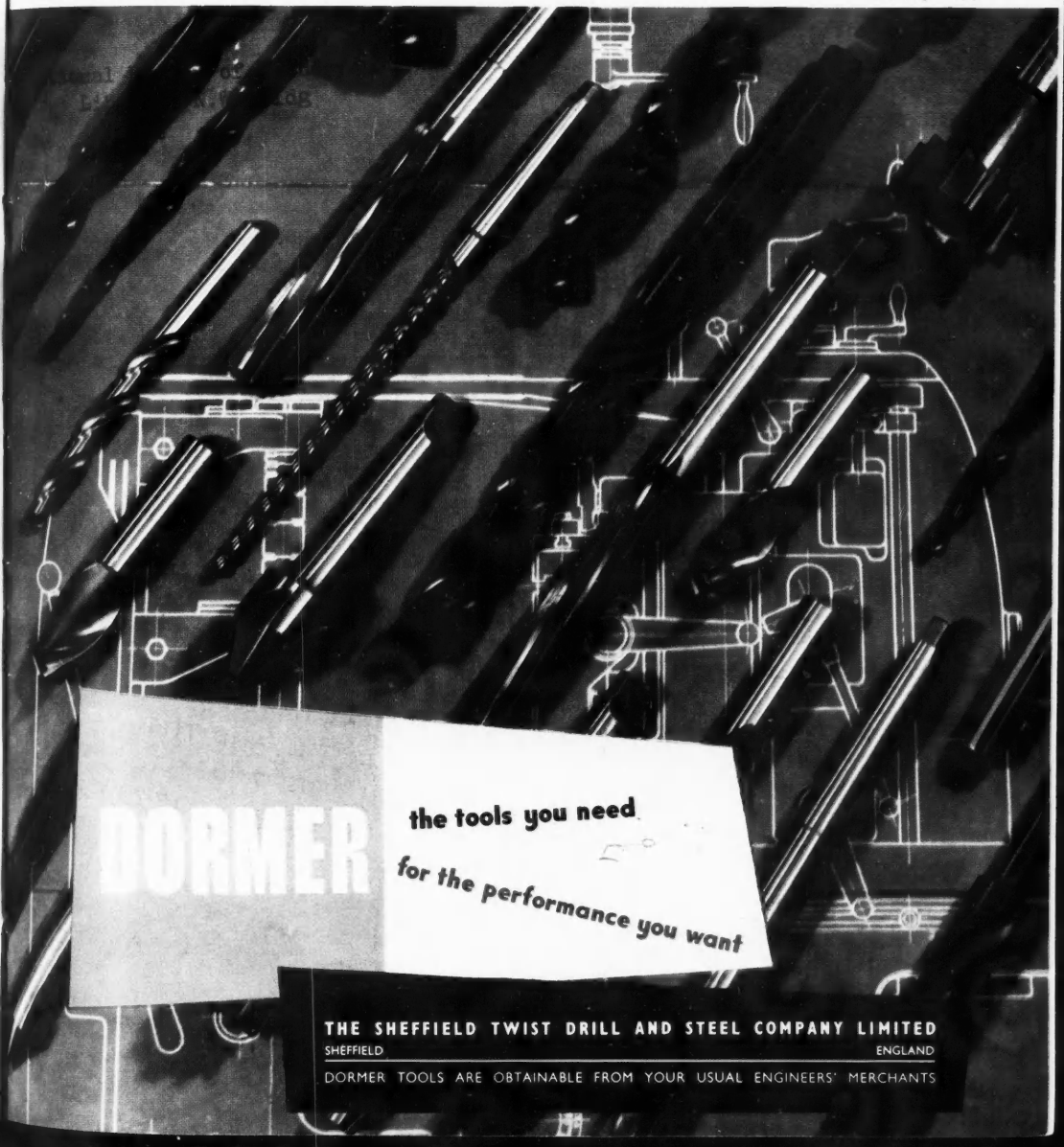
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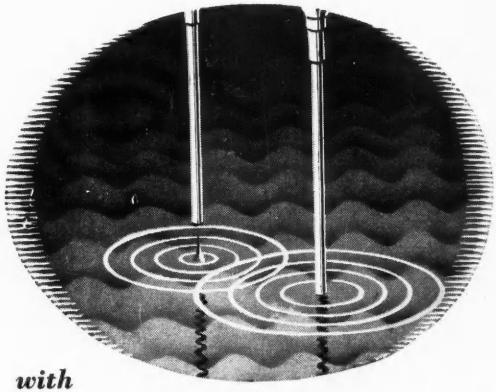

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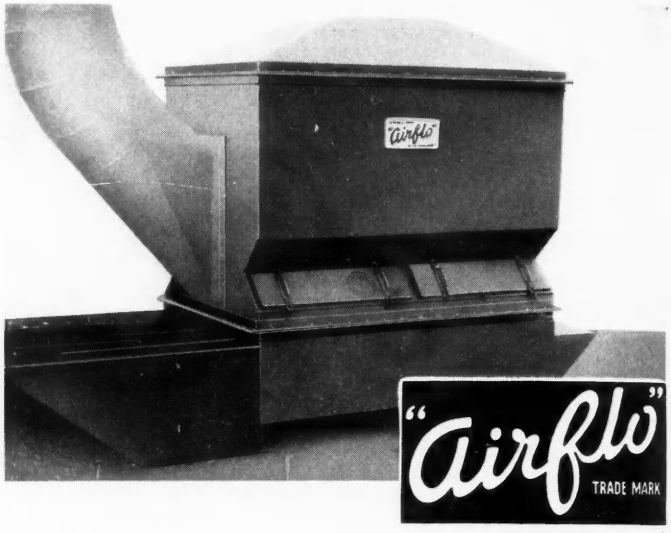

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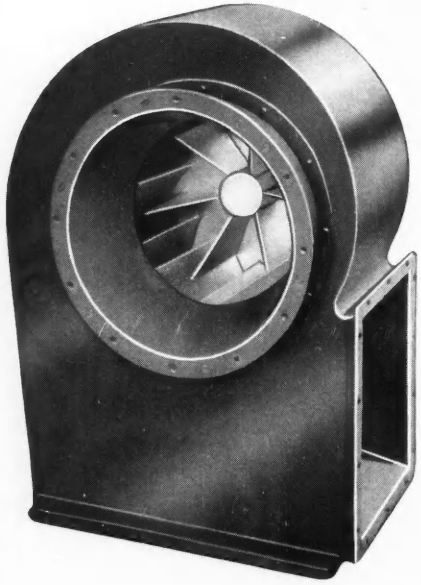

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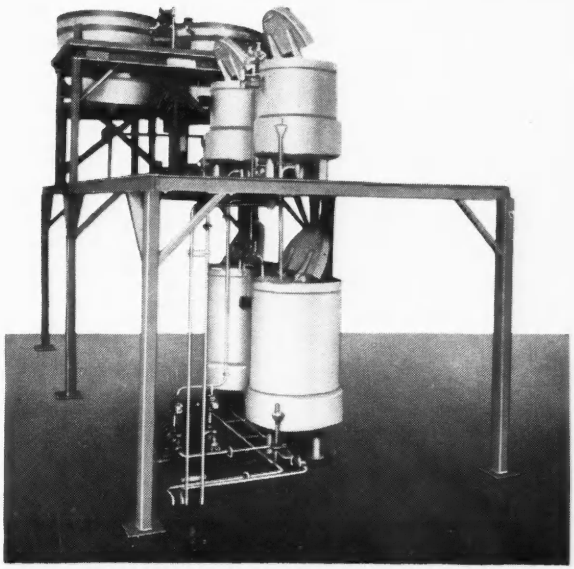

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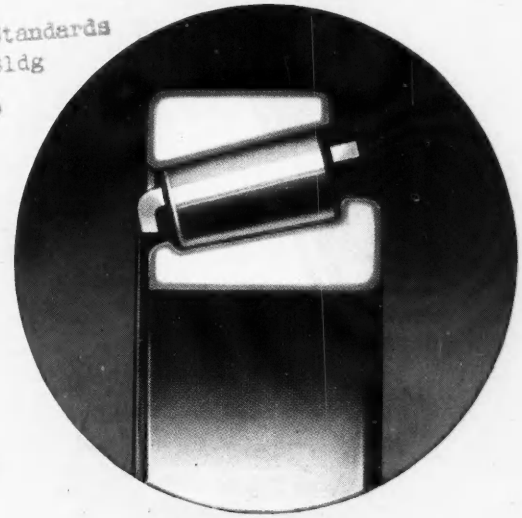

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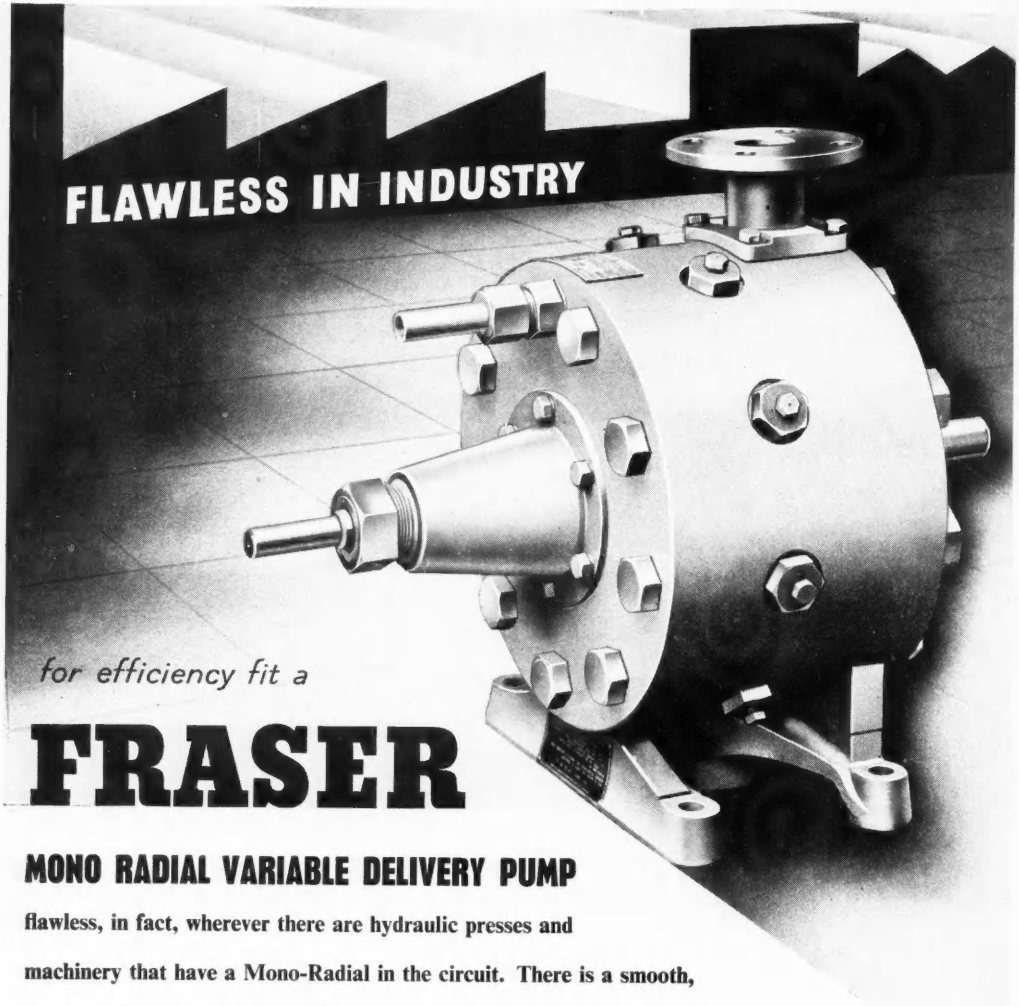

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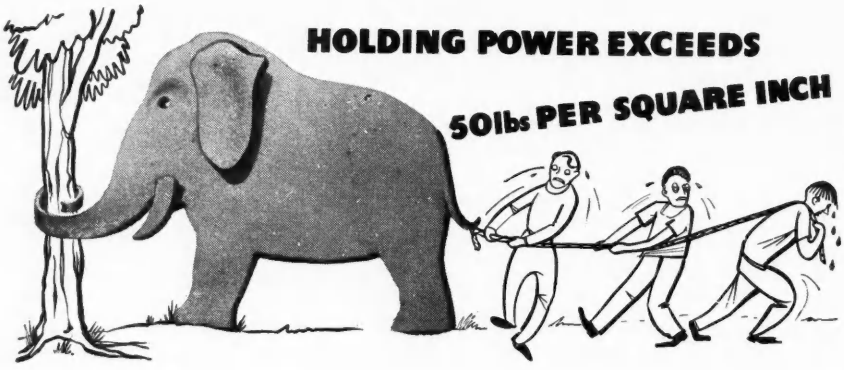

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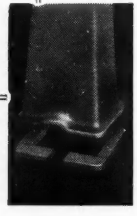

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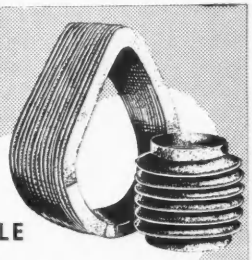

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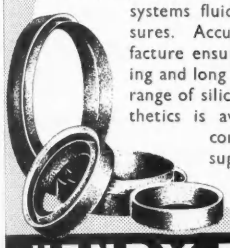

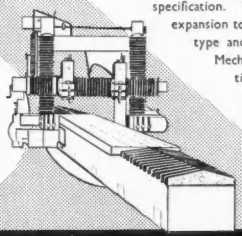

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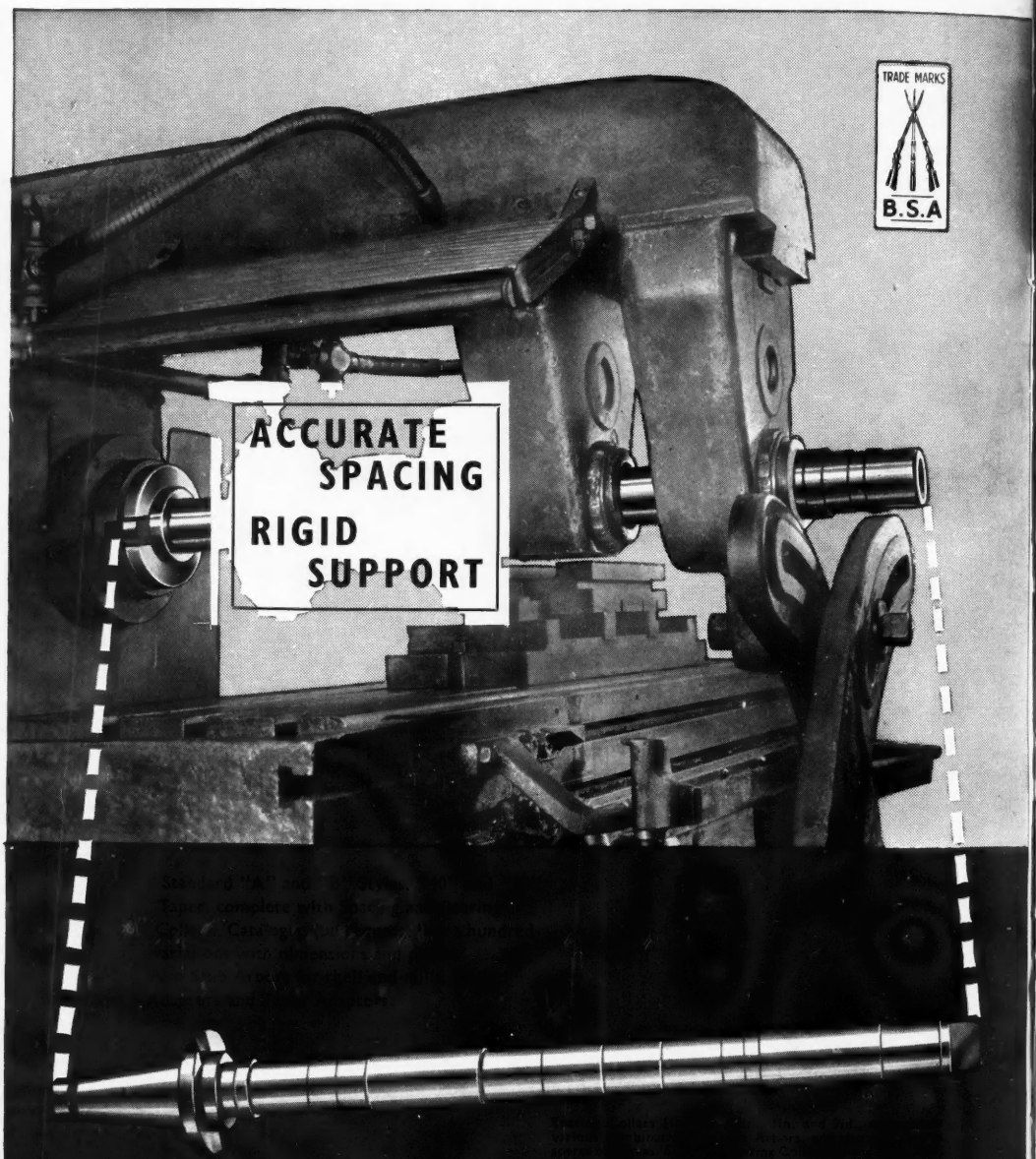

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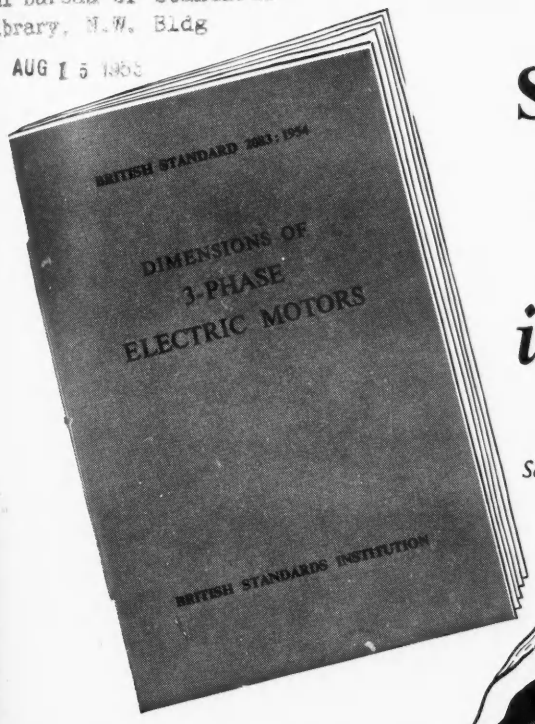

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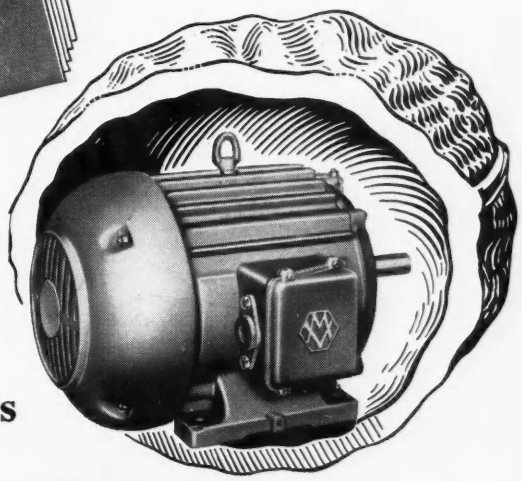

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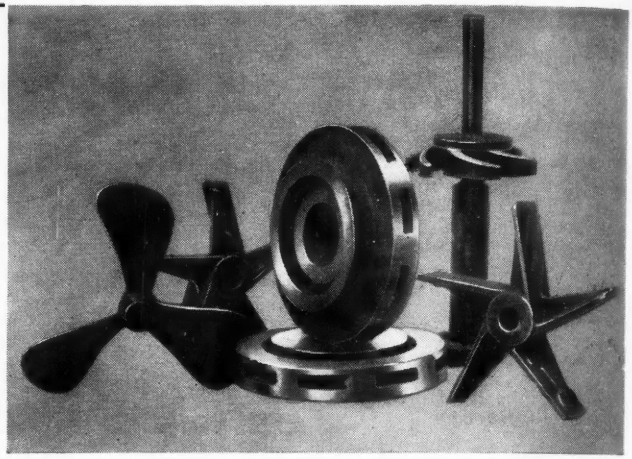

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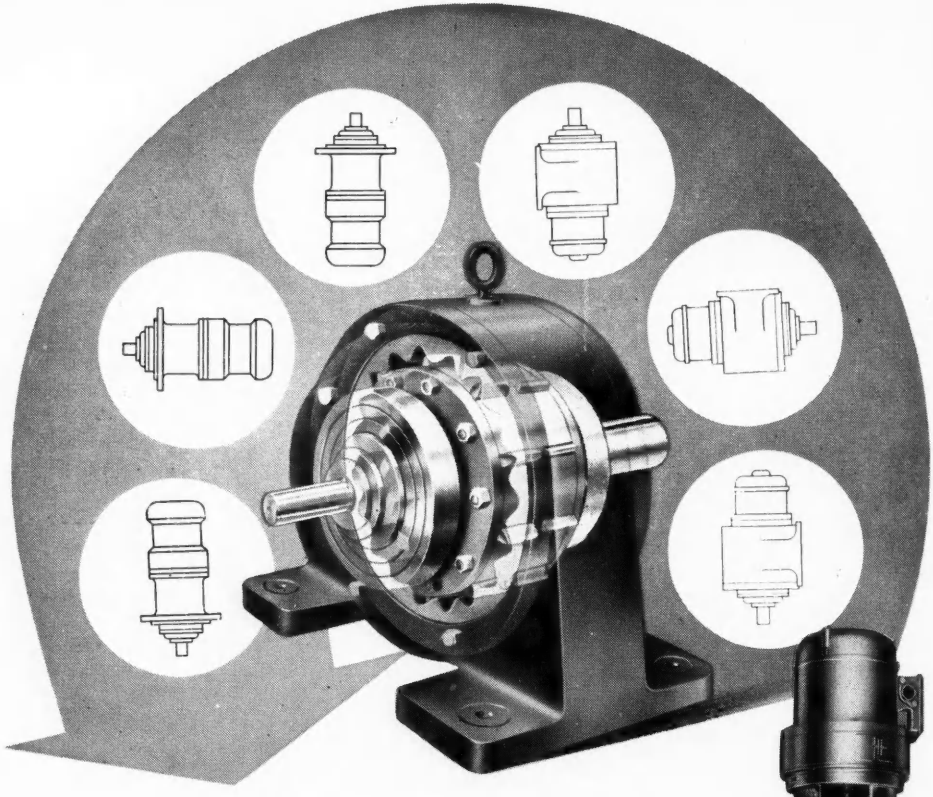

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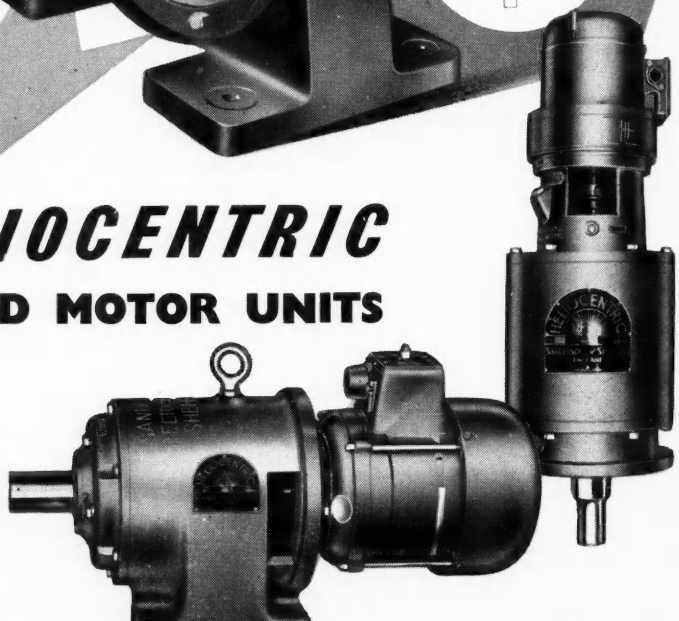

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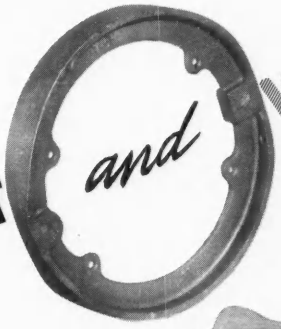

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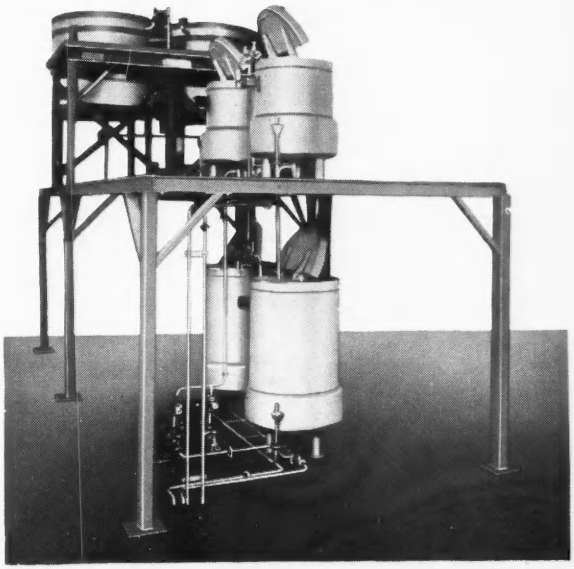

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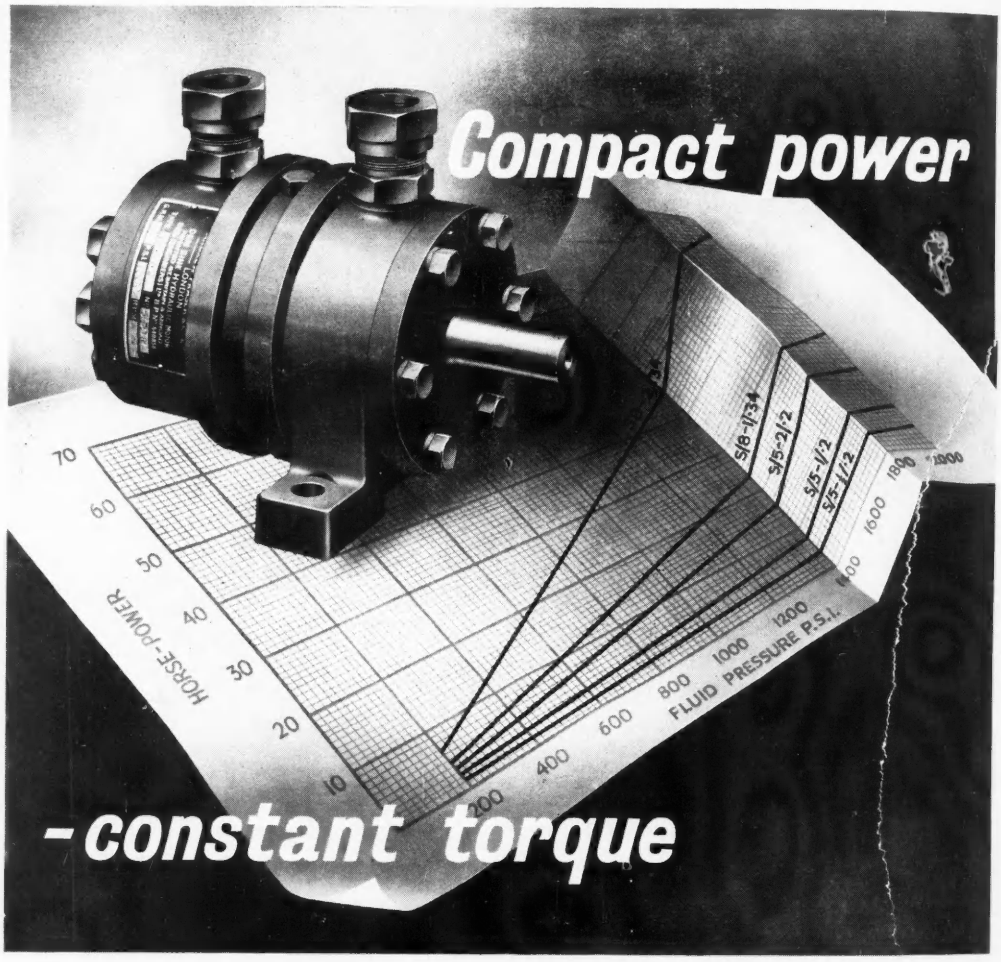

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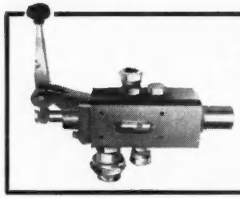

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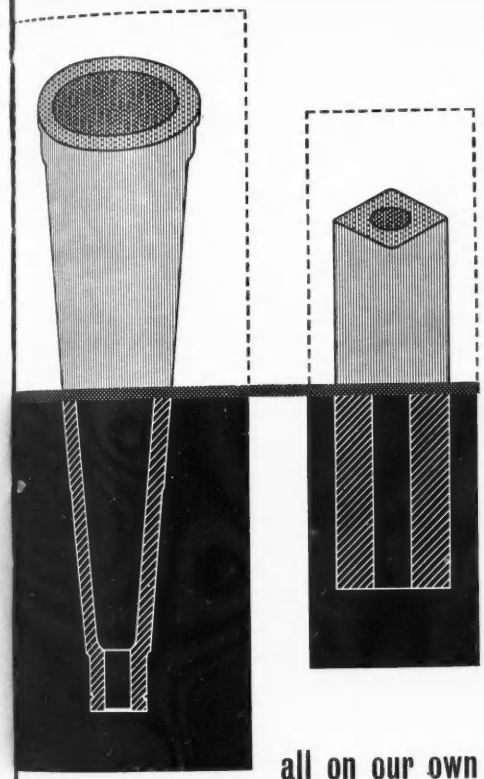

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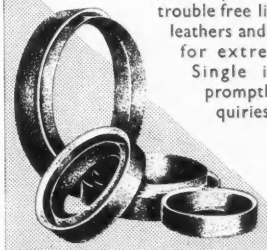

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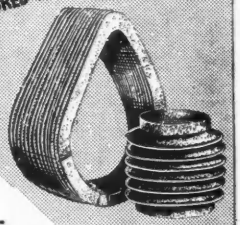

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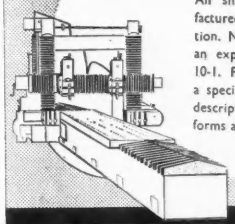

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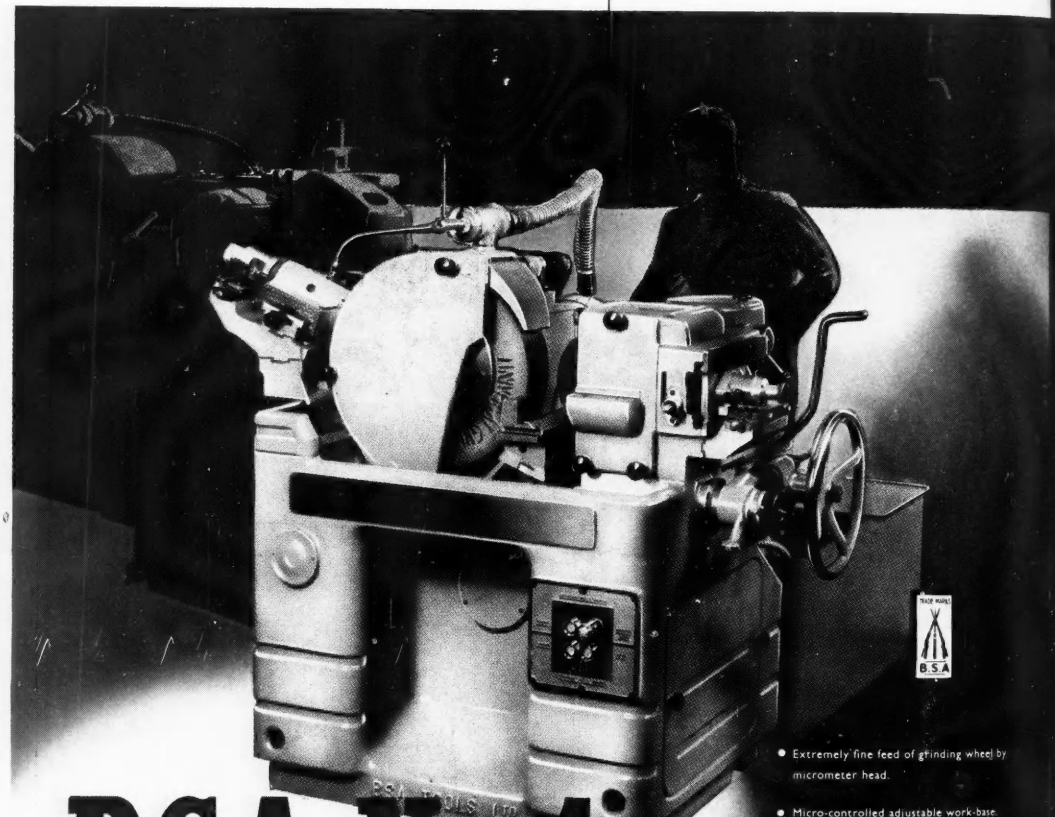

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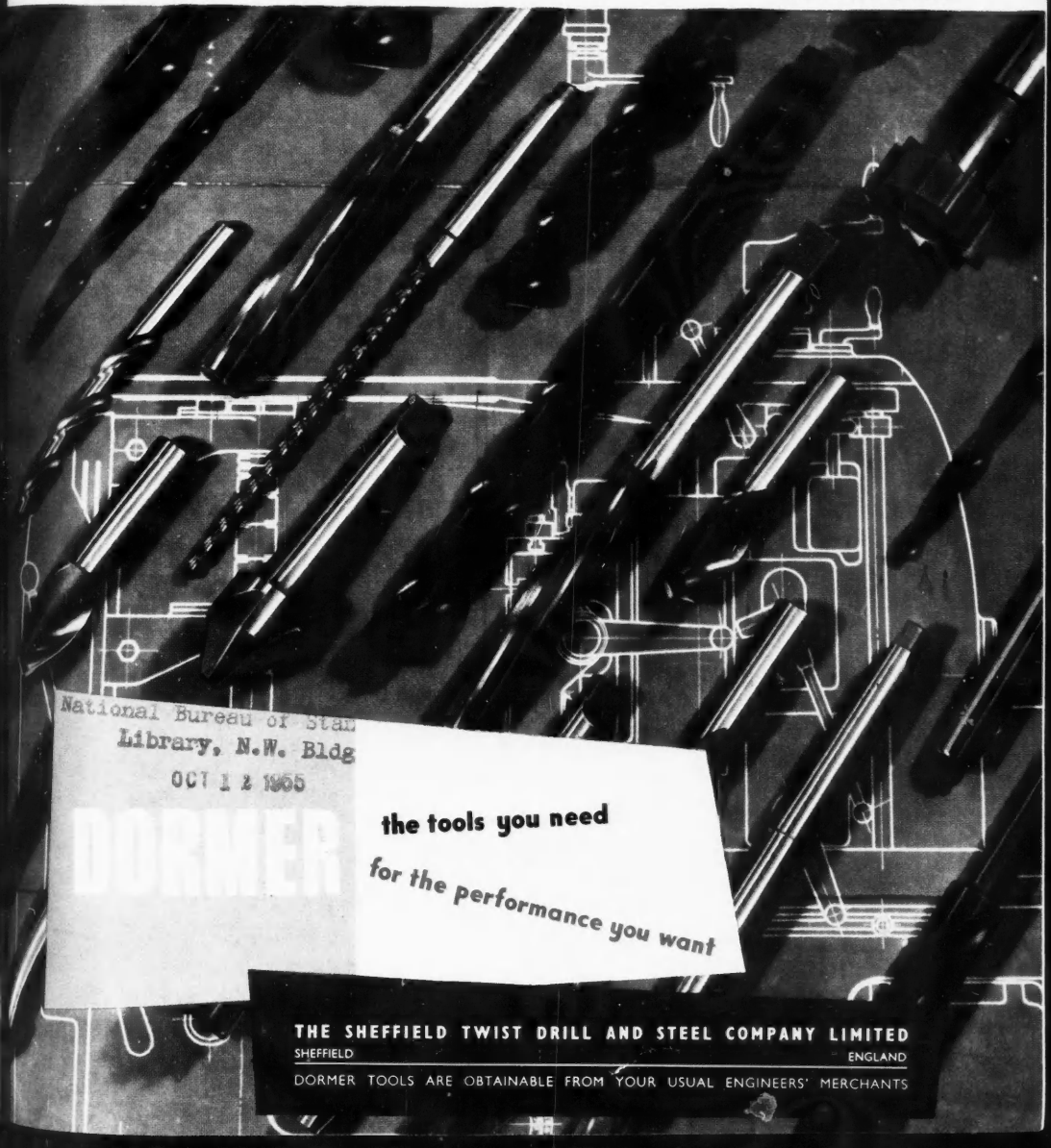

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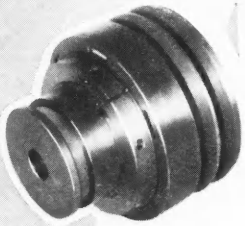

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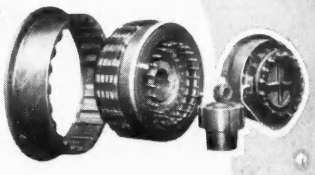

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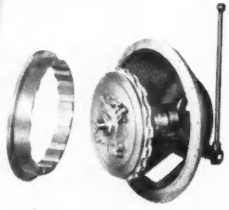

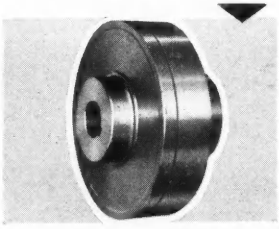

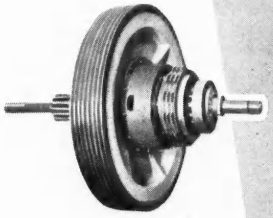

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REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XVI. No. 9 SEPTEMBER, 1955

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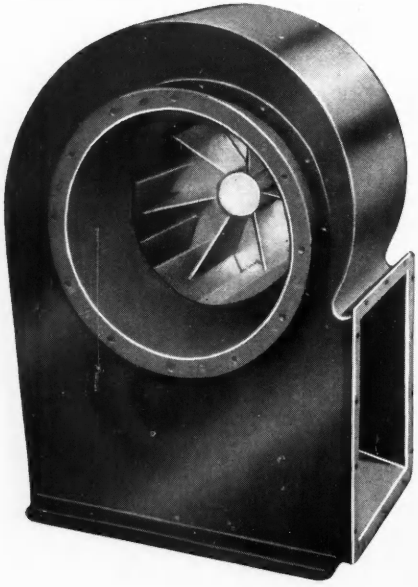

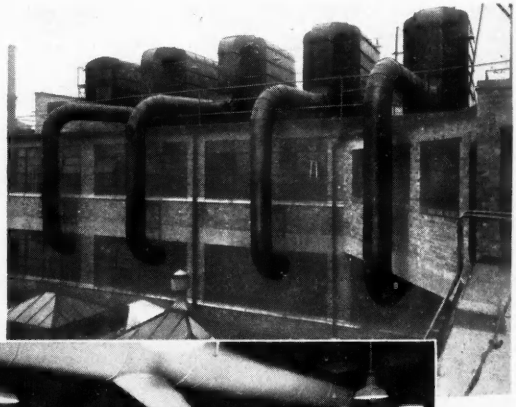

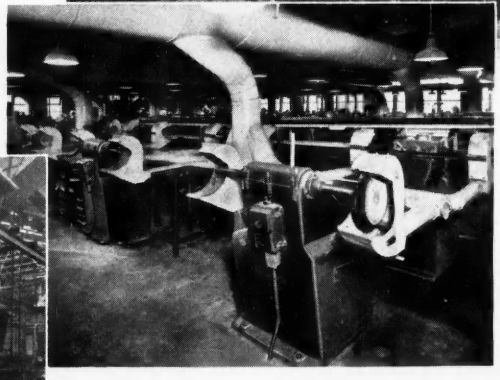

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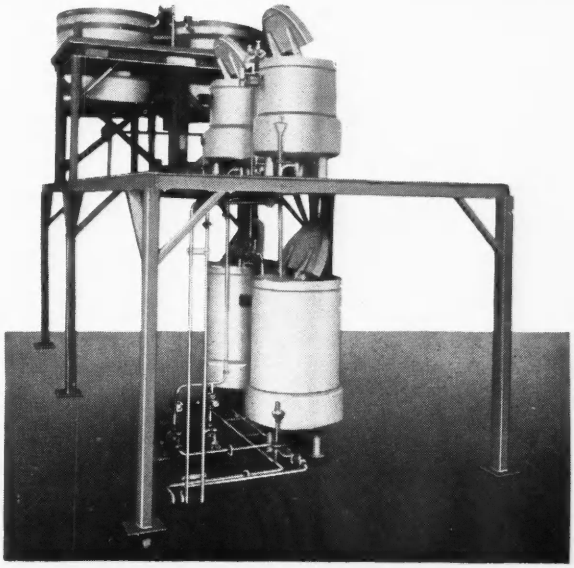

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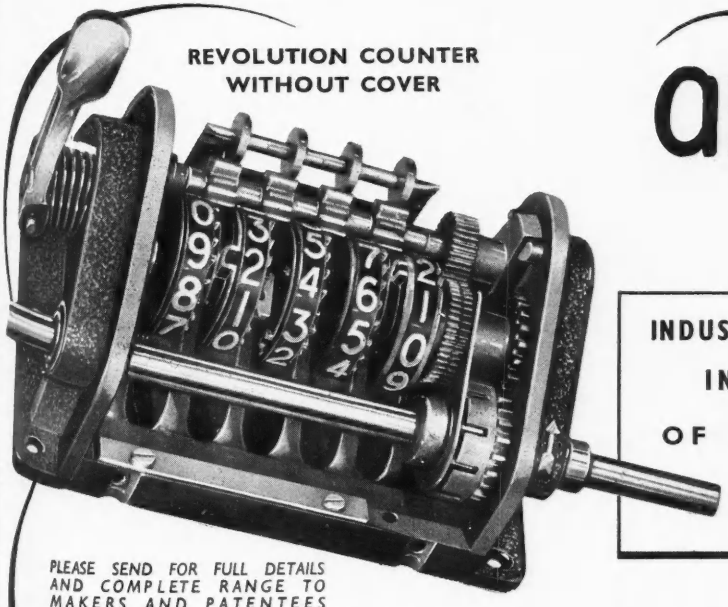

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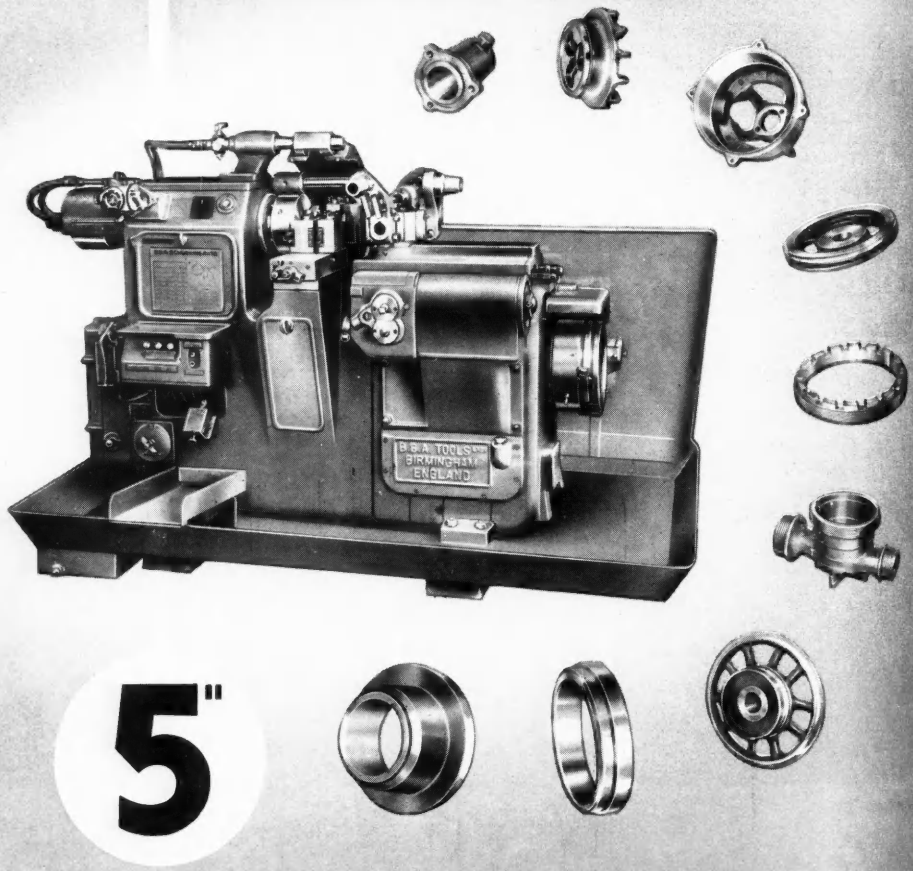

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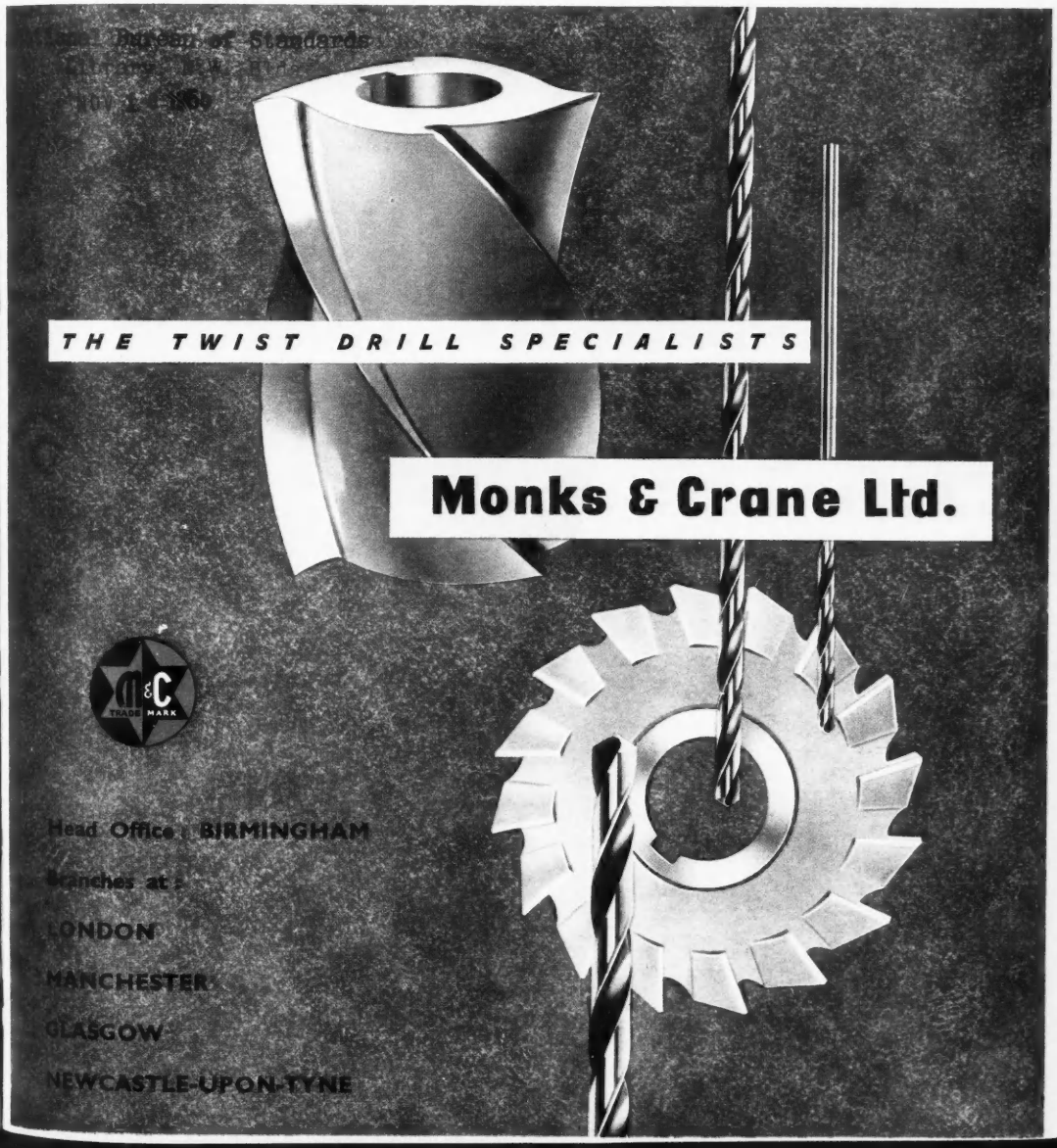

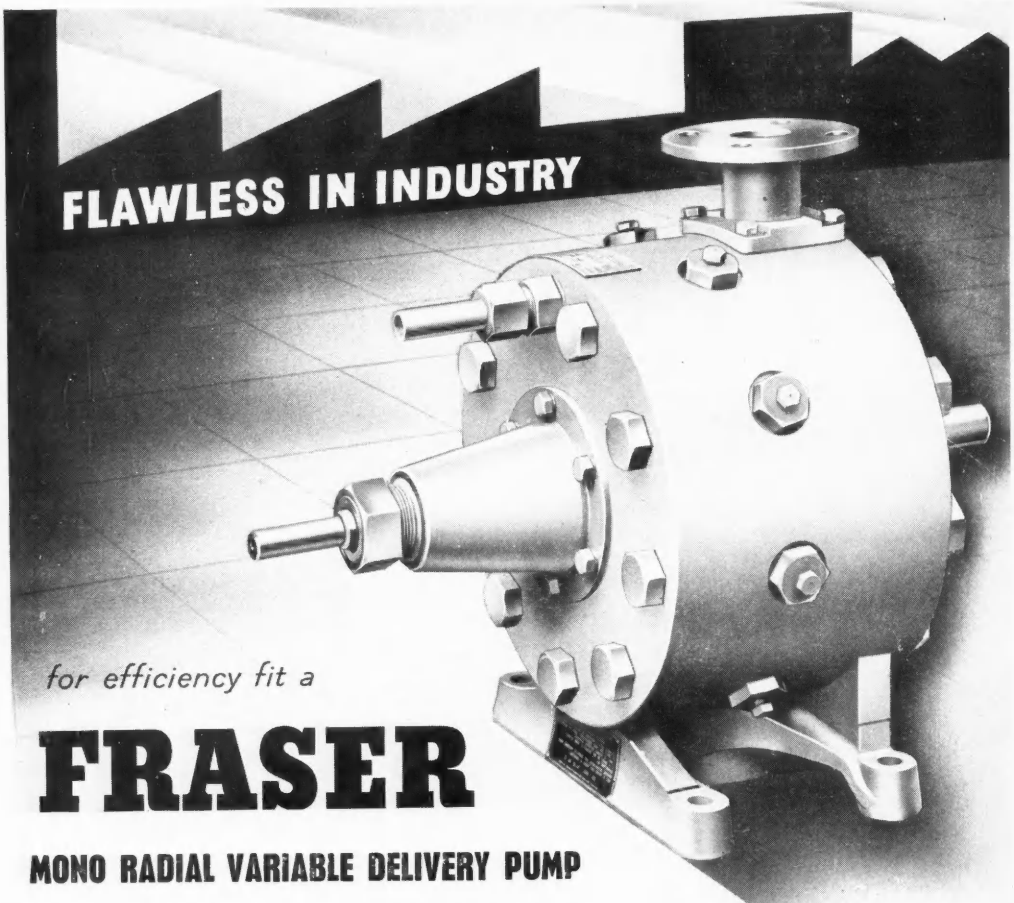

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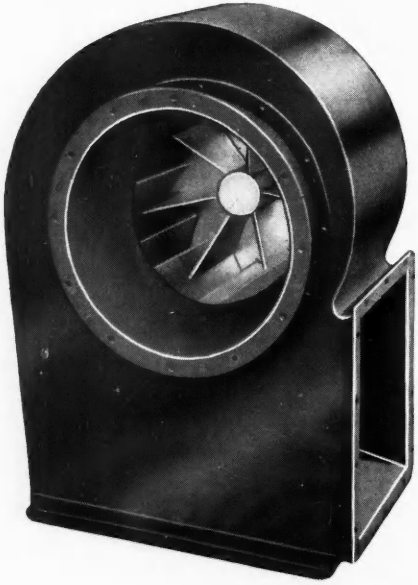

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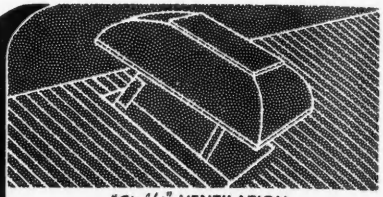

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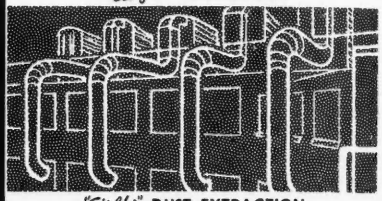

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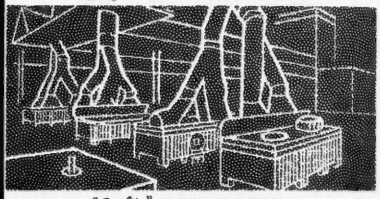

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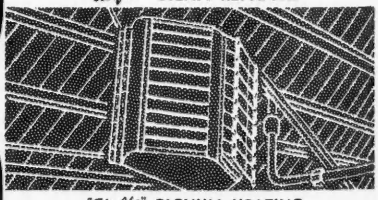

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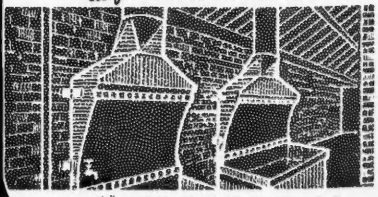

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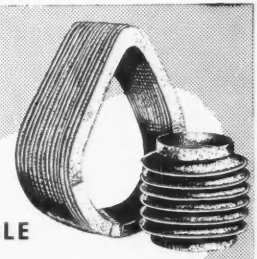

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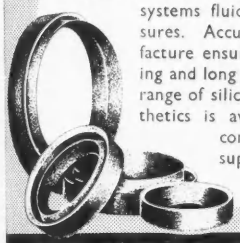

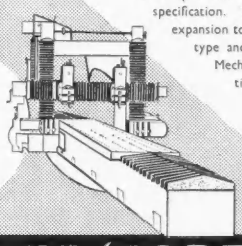

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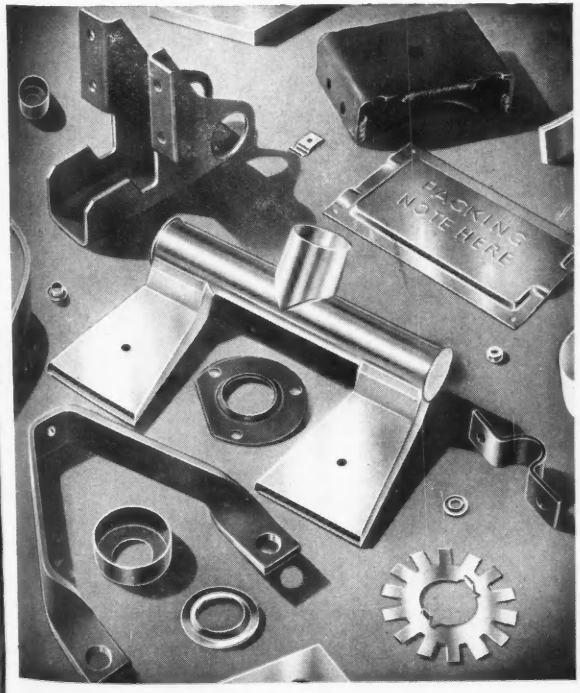

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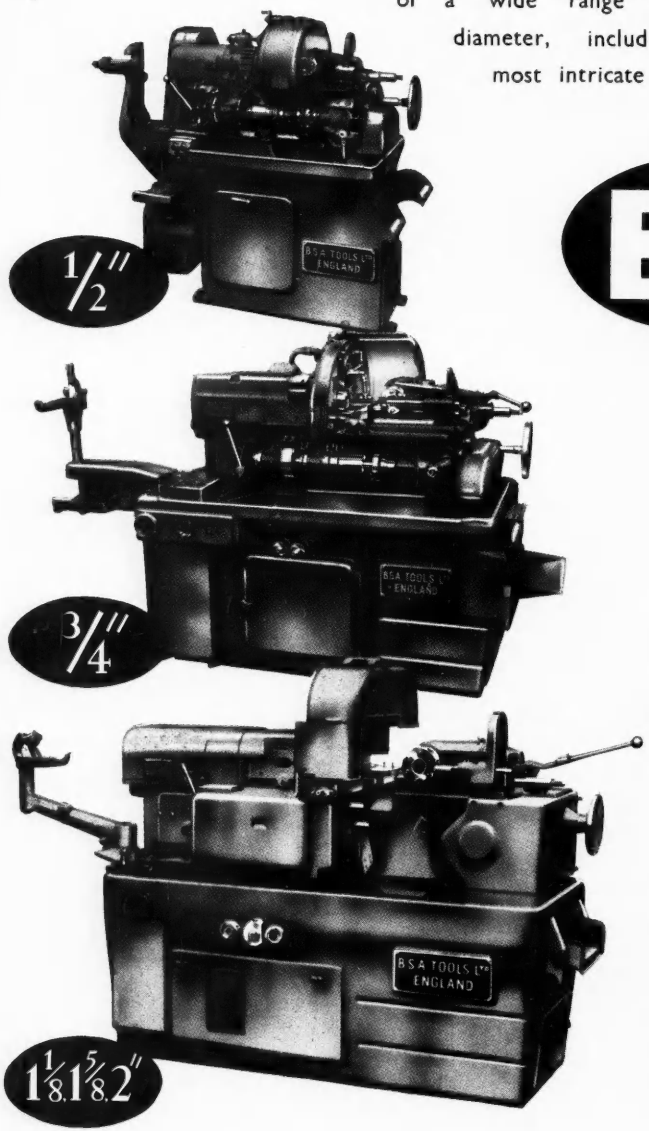

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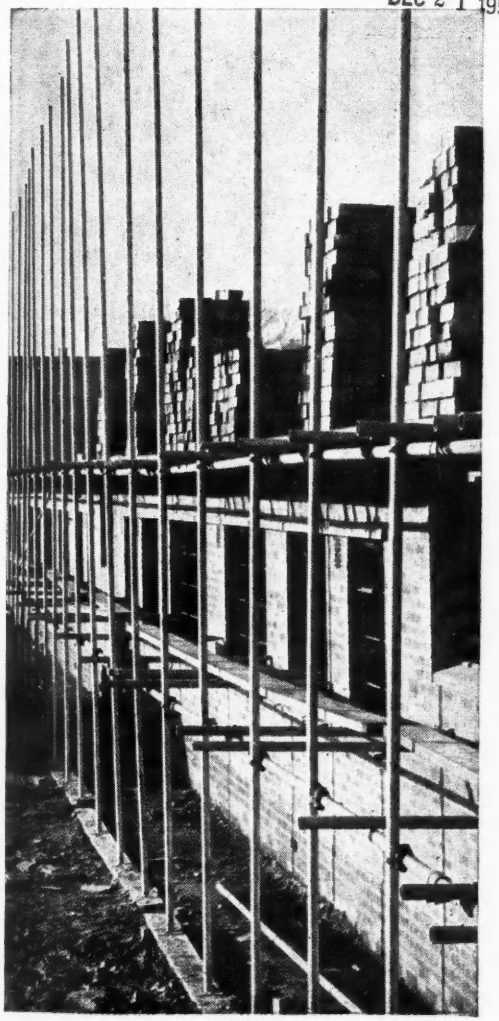

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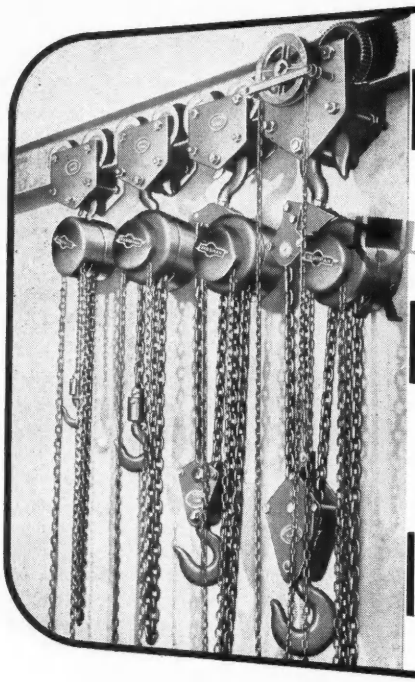

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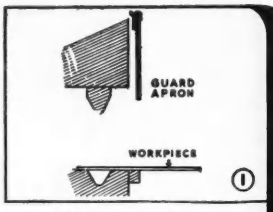
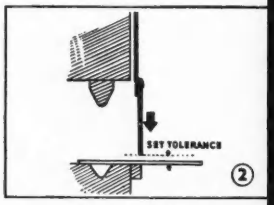
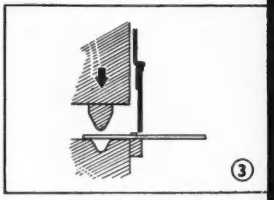


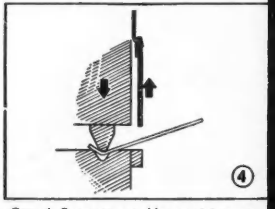
Up Position of Guard.



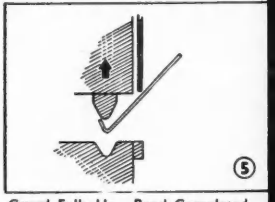
Down Position.



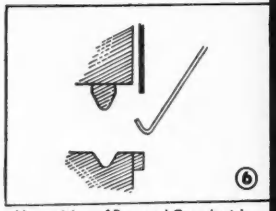
Guard locked Down with Air Pressure.



Guard Returns to Up position as beud begins to take place.



Guard Fully Up. Bend Completed. Ram starts to Return.



Up position of Ram and Guard with unhindered withdrawal of Work piece.

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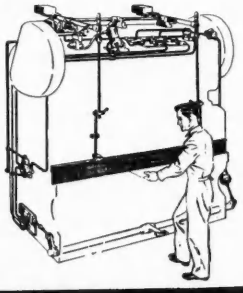

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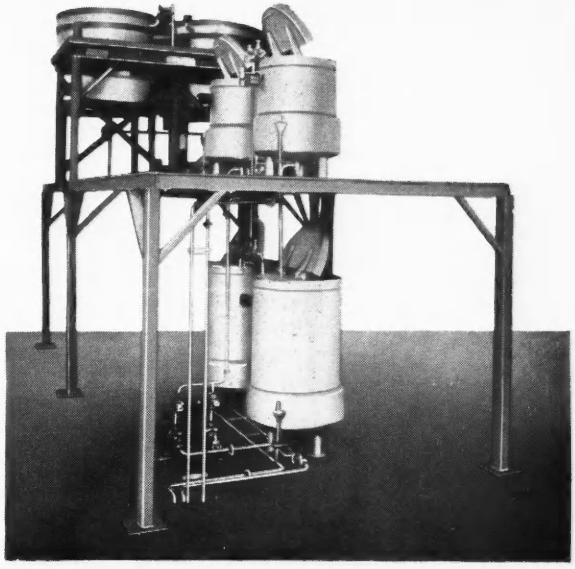

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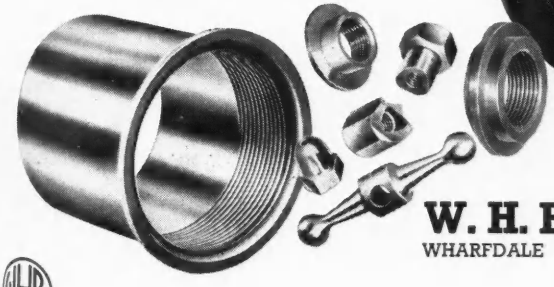

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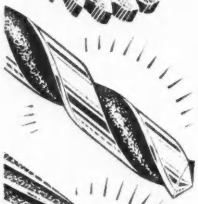

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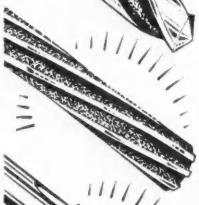

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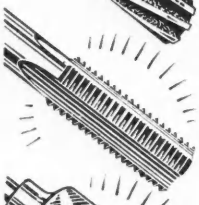

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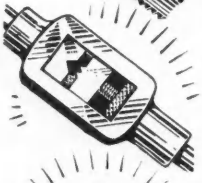

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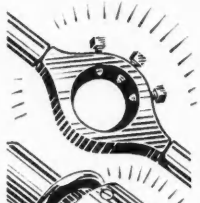

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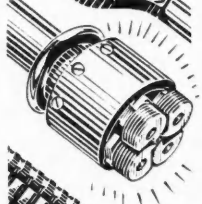

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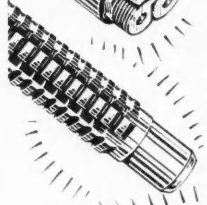

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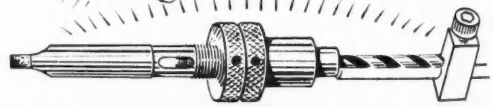

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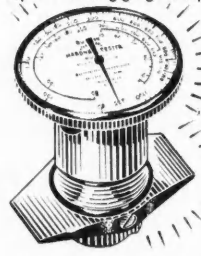

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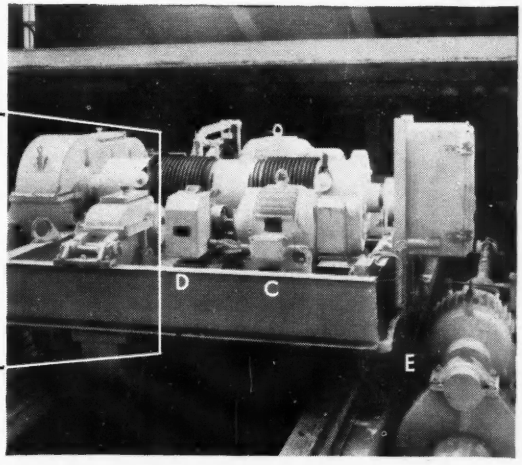

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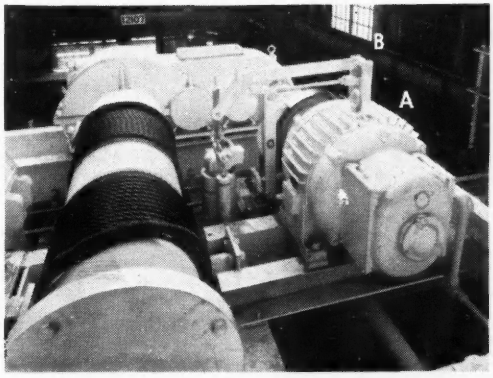

In the illustration (left) A is the 18-h.p. 720 r.p.m. hoist motor fitted with Stacreep thrustor control B. The long-travel drive, motor E, is shown at the top of page. The 3 h.p. cross traverse motor is seen at C and the 6-inch Perigrip brake at D.

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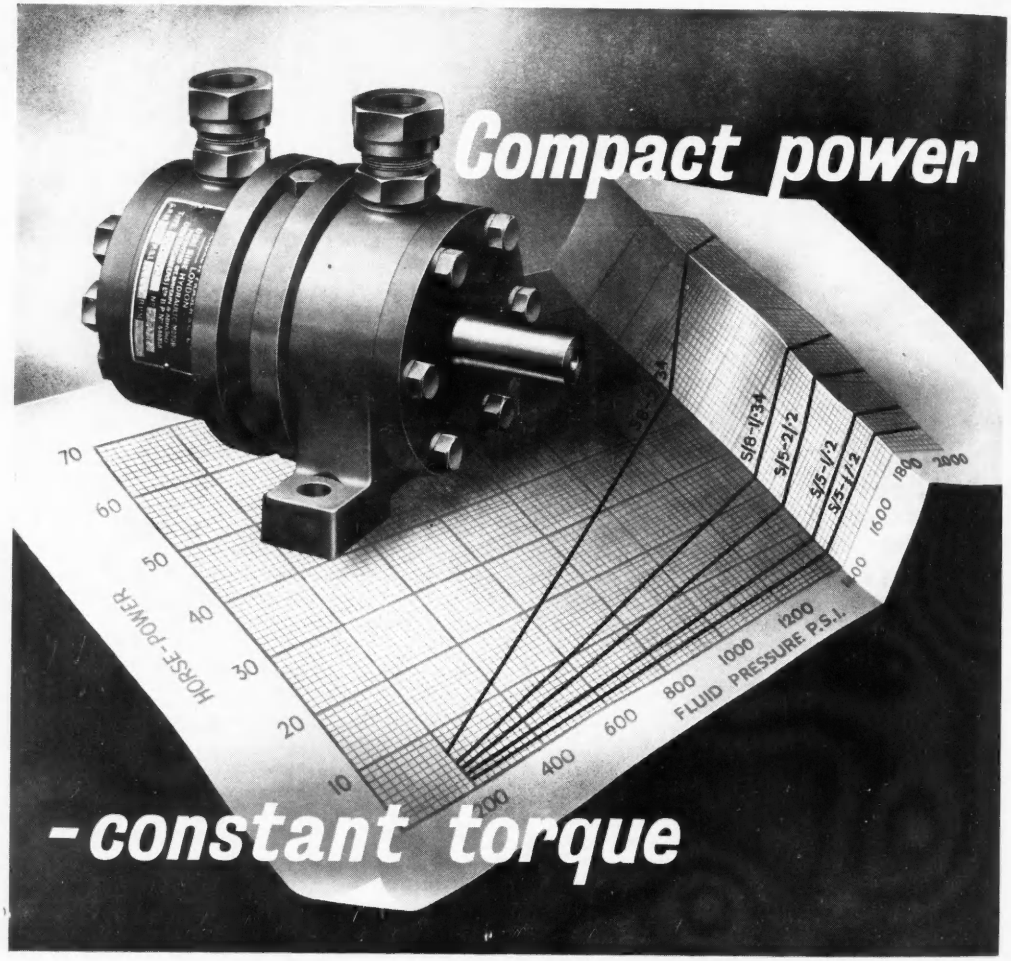

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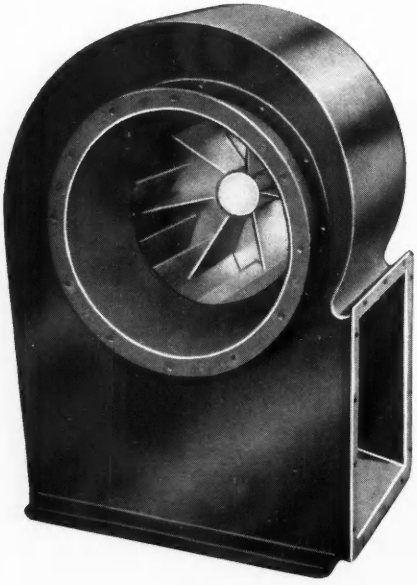

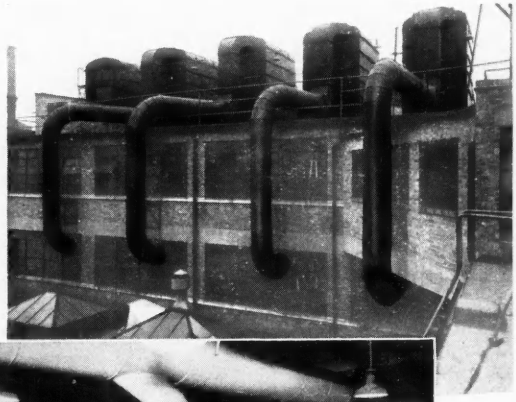

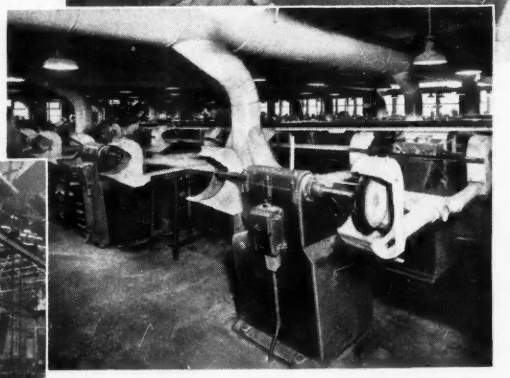

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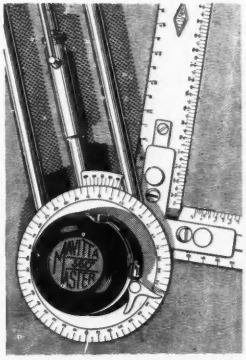

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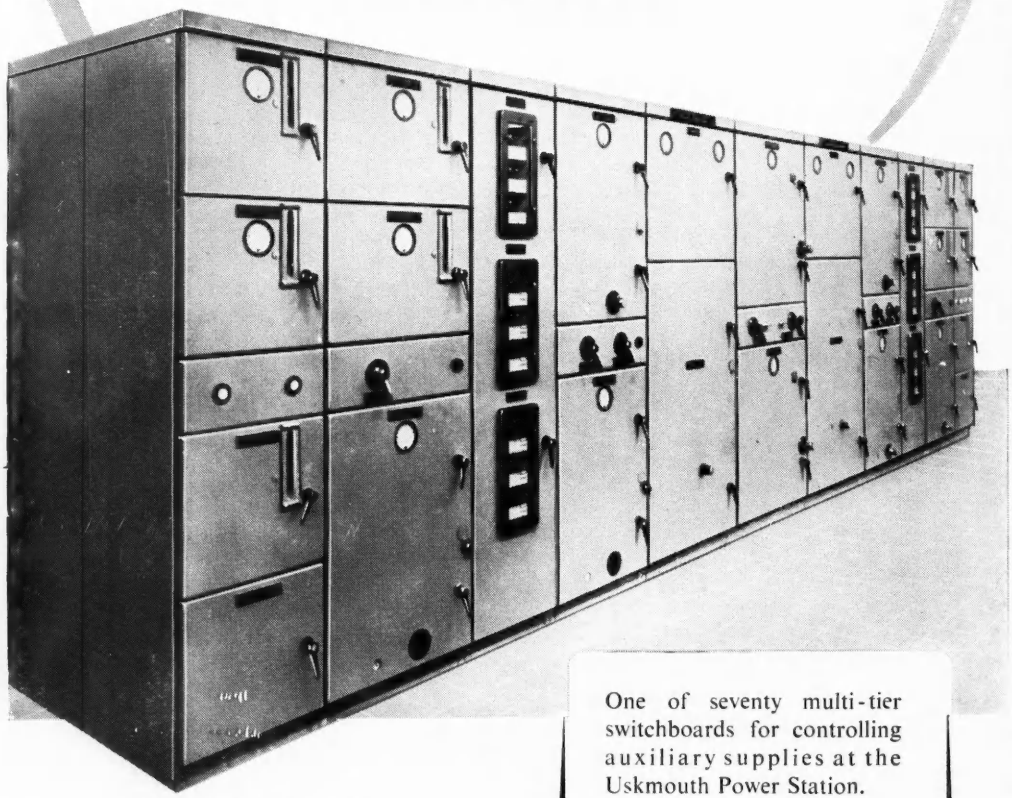

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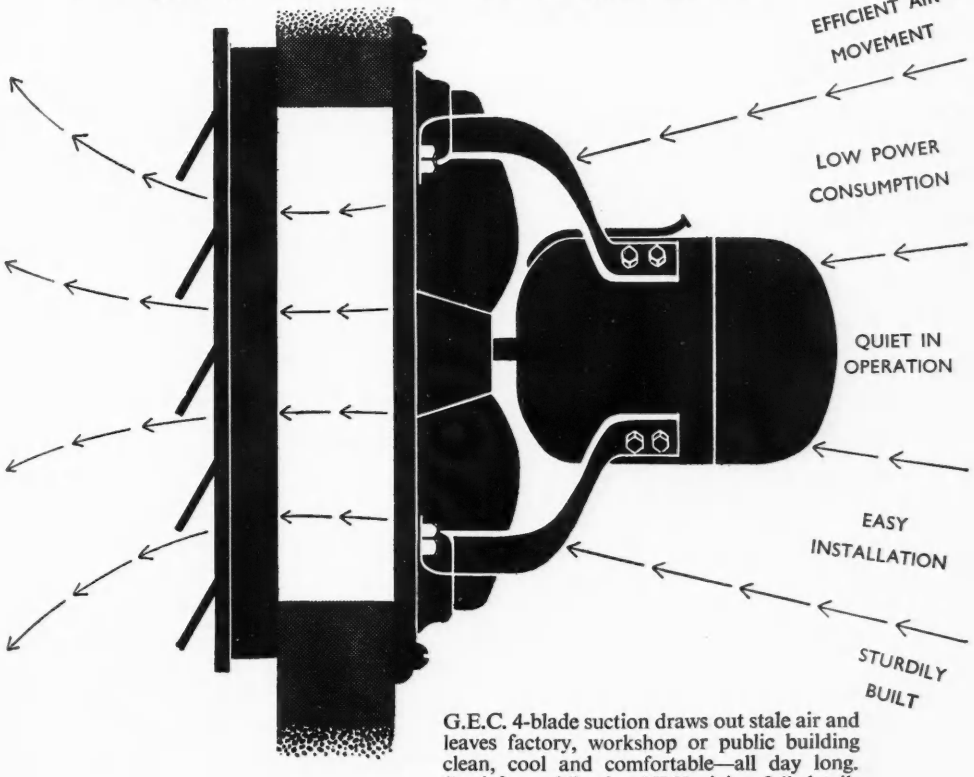

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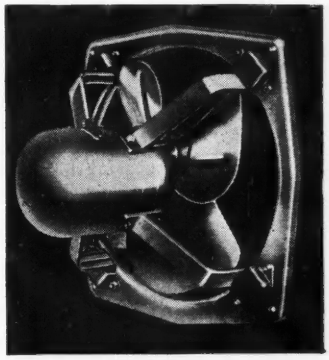

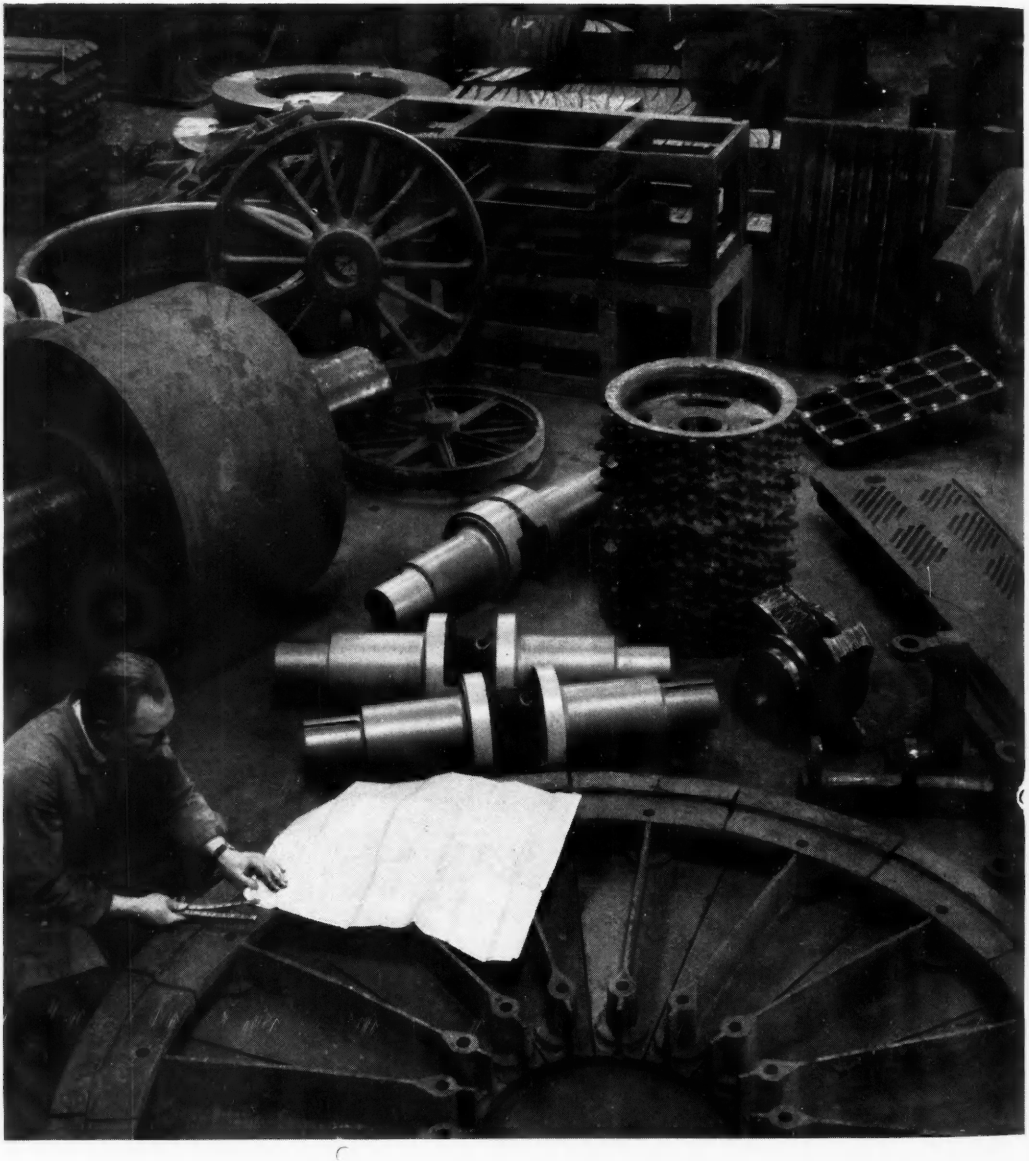

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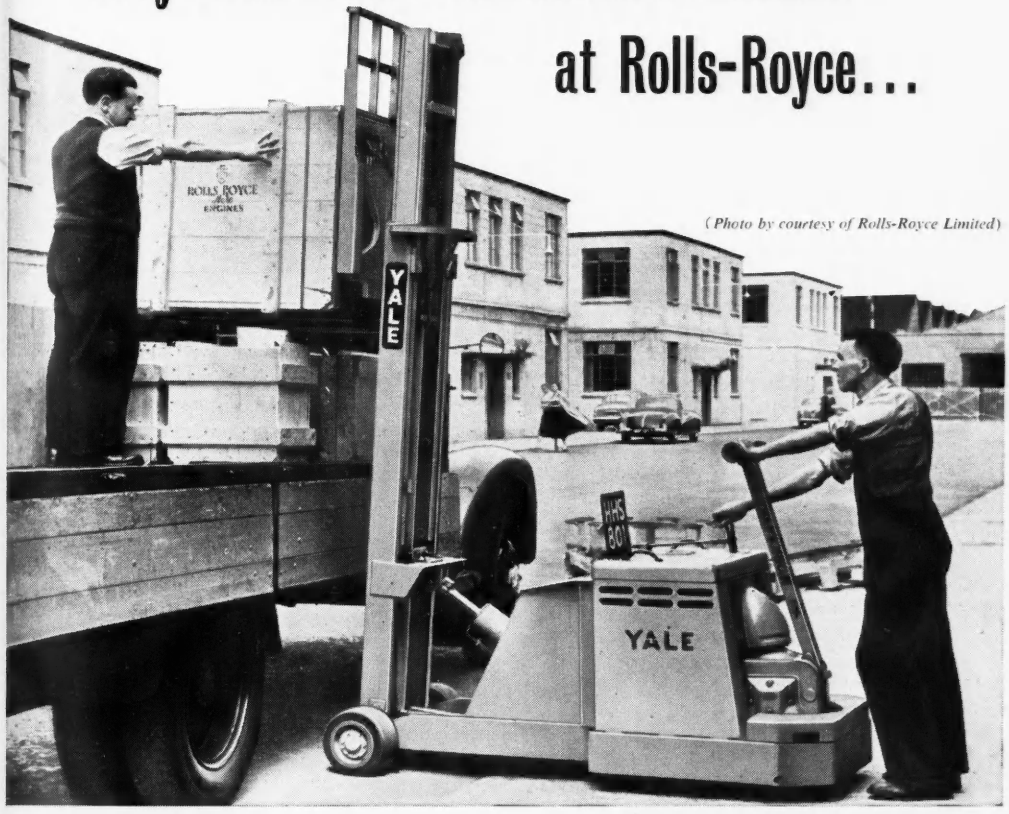

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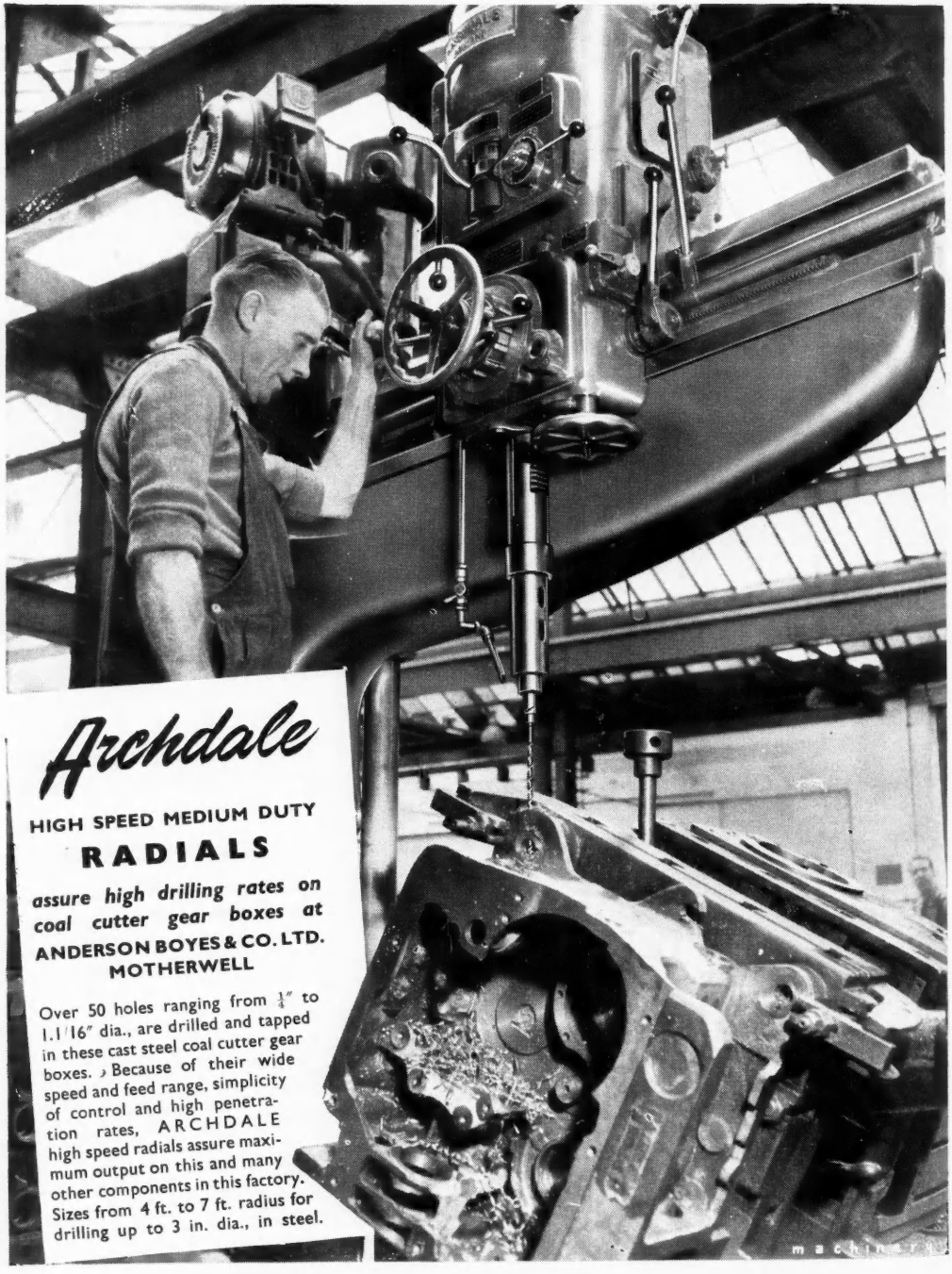

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assure high drilling rates on coal cutter gear boxes at

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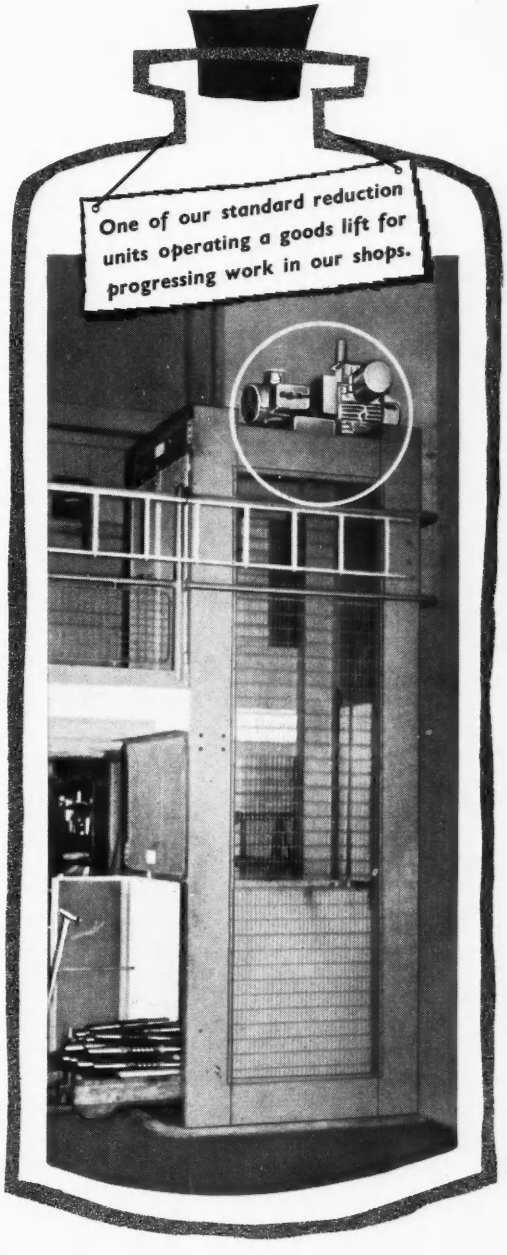
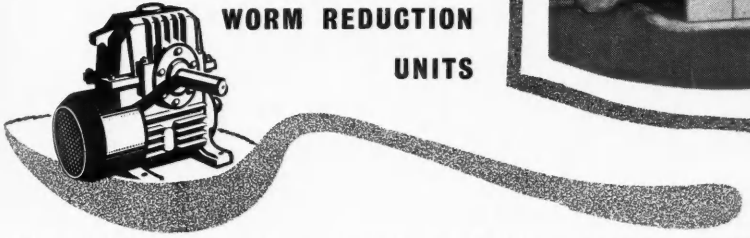
A Standard Type Holroyd Worm Reduction Unit can be made up from stock, packed, despatched, and delivered to you fairly quickly. Worms, wheels, and special units made to order take somewhat longer. For information on Worm Units and applications (and we're discovering new ones every day, like the Goods Lift in the illustration) drop us a line at Milnrow, Lancs. We'll be glad to help you all we can.



Holroyd

WORM REDUCTION UNITS



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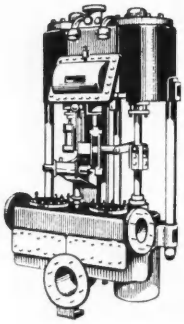

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Crowthorn lathes play an important part in the production programme of Messrs. Thom, Lamont & Co. Ltd. of Paisley.

A Crowthorn 15″ × 14′ 9″ gap bed lathe is engaged on general production work, machining components for the pumping equipment which is famous the world over.

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A Crowthorn 15″ × 14′ 9″ gap bed lathe precision machining a removable gunmetal liner — a feature of these high-class pumps.

Lathe supplies by Messrs. Welling and Welling Ltd., 4 Victoria Street, London, S.W.1.

Photograph by courtesy of Messrs. Thom, Lamont & Co. Ltd., Paisley.

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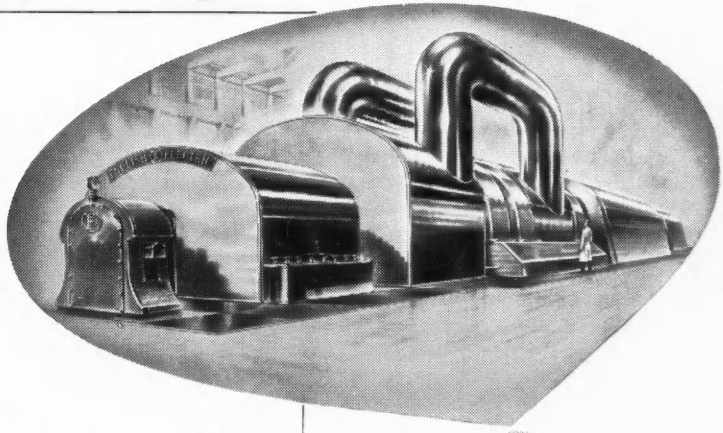
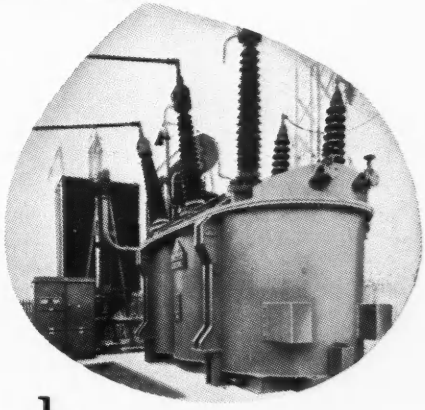
so many things...



This artist's impression shows one of three 200 MW turbo-generator sets now being built by 'ENGLISH ELECTRIC' for installation in the new power station which the Central Electricity Authority, subject to Ministerial consent, proposes to build on the River Trent at High Marnham. Each of these units is more than three times as powerful as the largest and latest 3,000 r.p.m. generating units yet in service in Britain and each will have a higher output than most of the complete power stations now operating.

The 275 kV transformer shown here was the first to be supplied to the Authority for service at this voltage.



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Offices and representatives throughout the world.

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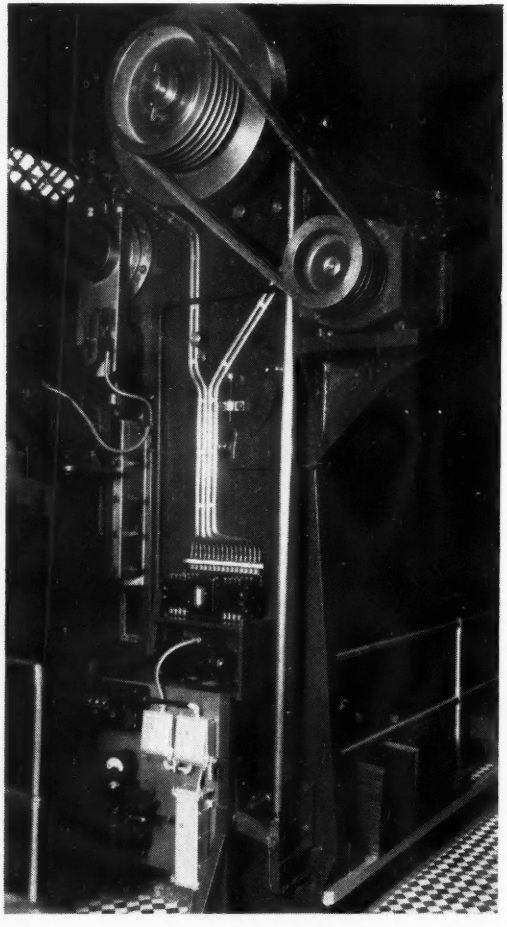

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fitted to a press manufactured by
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Versatility in oil lubrication with the 'Brentford' system

The ' Brentford ' system of continual lubrication is entirely automatic. It is extremely versatile since each pumping unit—and there are from 1 to 24 of these—can be adjusted individually to deliver the right amount of oil to every bearing.

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' Brentford ' Automatic Lubricators are at work in almost every industry, on many kinds of machine. Reductions in breakdowns have been estimated as up to 80%, with resultant increases in production and safety, and savings in the oil and power used.

The ' Brentford ' is one of the wide range of lubrication systems produced by Tecalemit and used throughout industry.

Tecalemit technical representatives are always ready with advice and information; fully experienced fitters handle any installation if required.

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The Authority on Lubrication
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Does *filtered* or *unfiltered* oil reach the engine during the first few minutes after starting from cold? That is the vital question when considering the choice of filters—for this is the time when excessive wear can easily be caused.

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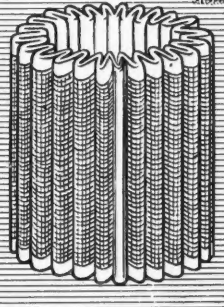

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There are many factories where such conditions do exist; where resources are being drained day after day and management seems unaware of it. Bad visual environment at bench or machine is a frequent cause of tiredness and fatigue; the worker is less alert, and the result is seen in greater spoilage, accidents, absenteeism.

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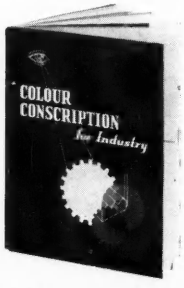

COLOUR ADVISORY SERVICE. This department is staffed by artists trained in the principles outlined in "Colour Conscription."

Perspective drawings can be supplied for your guidance in following these principles; you are invited to make full use of this service.

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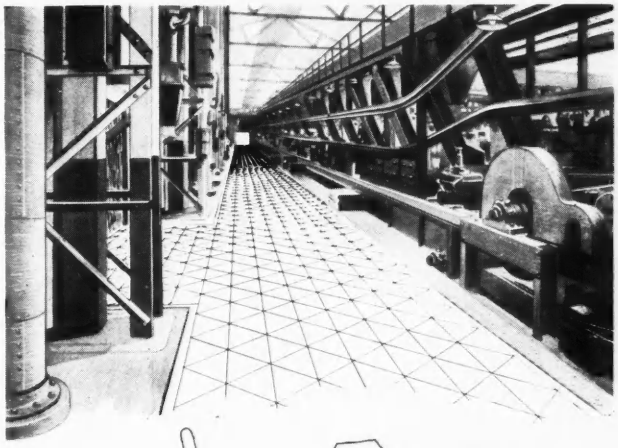

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Crazy paving is attractive in the right setting — but not in factories. Danger lurks in every crevice of badly laid flooring — danger to operatives and possible damage to equipment. A flooring which is speedily laid, mechanically level and above all, safe for *all* traffic is the Tri-Pedal Unit System of Iron Paving. It provides a permanent system of flooring which will stand up to the heavy wear and tear experienced in workshops and factories. Complete details of the Tri-Pedal System will be supplied on request.

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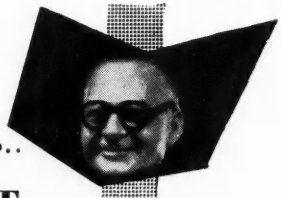

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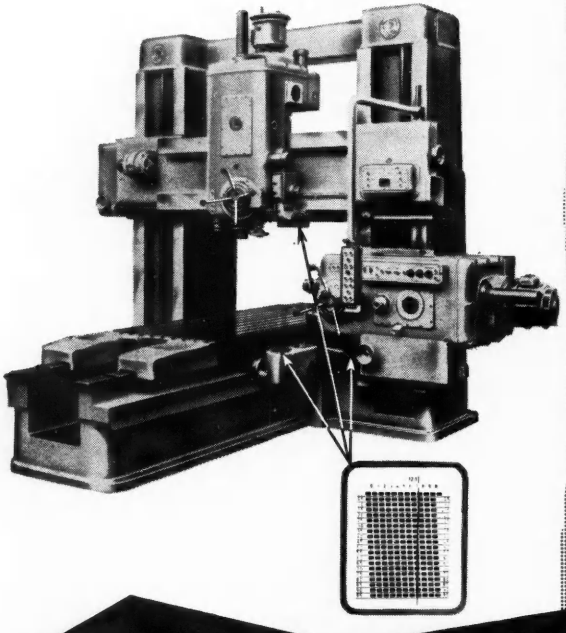

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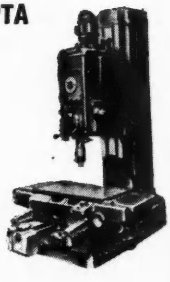

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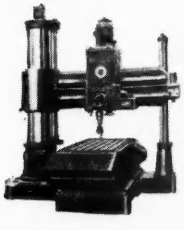

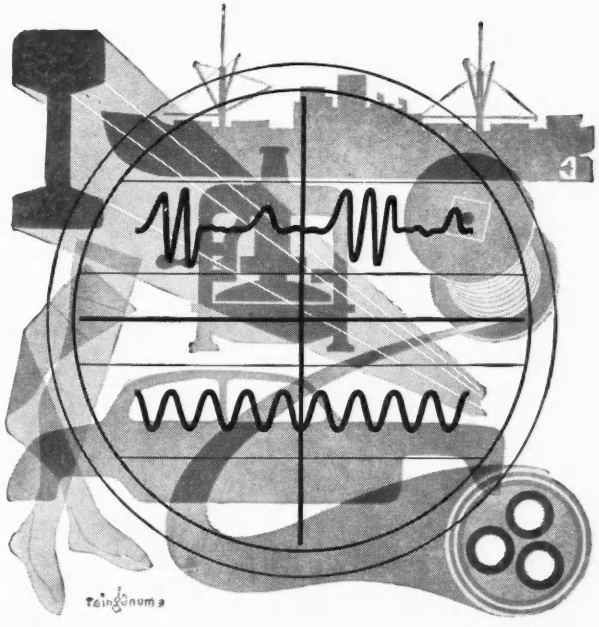

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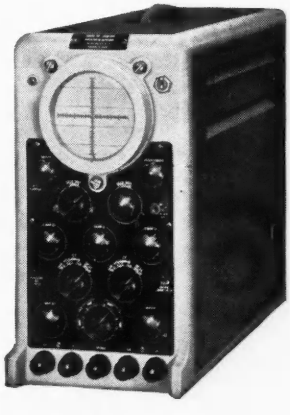

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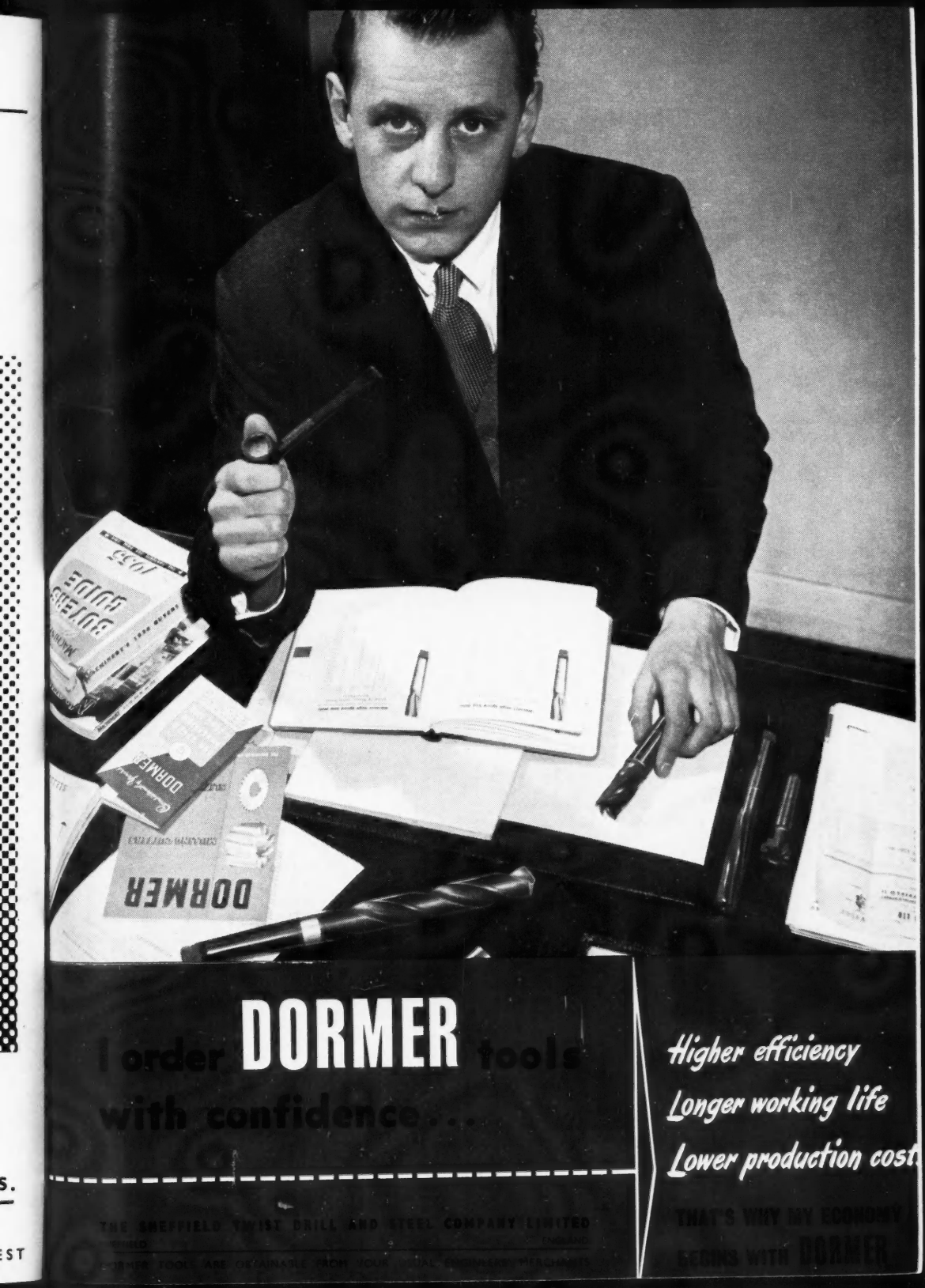

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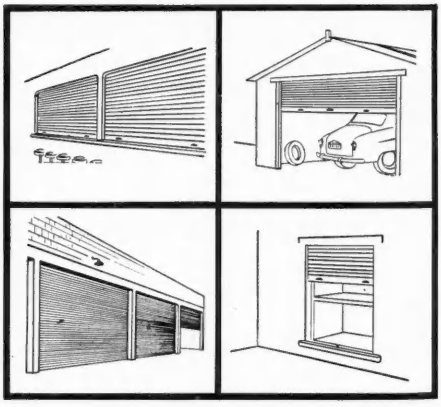

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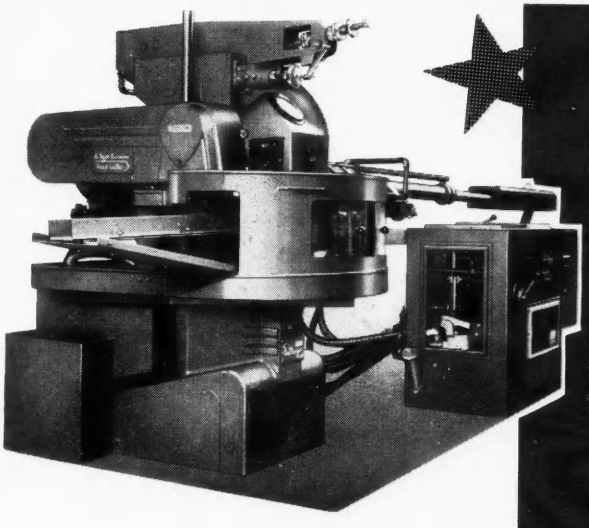

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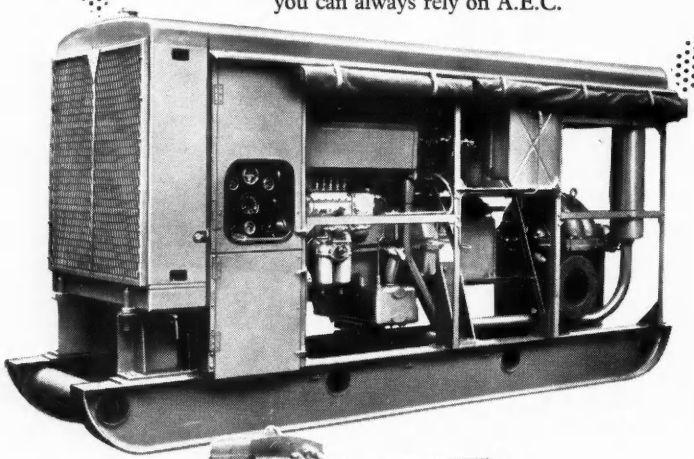
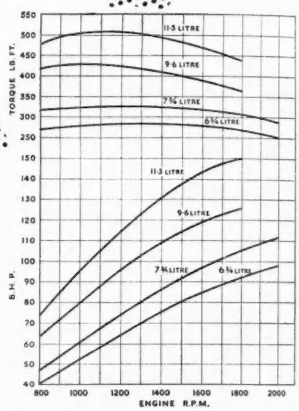
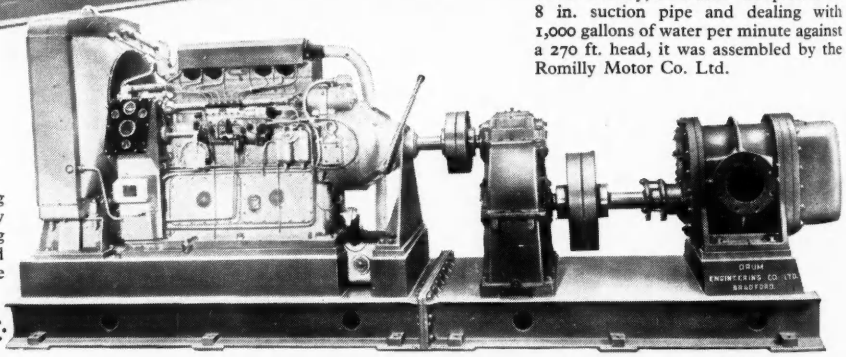




This Mather & Platt Pump, powered by a 9.6 litre A.E.C. diesel engine, is used by Sir John Jackson Ltd., for draining excavations on the N.C.B. open cast coal site at Carway, S. Wales. Coupled to an 8 in. suction pipe and dealing with 1,000 gallons of water per minute against a 270 ft. head, it was assembled by the Romilly Motor Co. Ltd.



This fuel bunkering pump unit was made by the Drum Engineering Co. Ltd., and is powered by an A.E.C. 9.6 litre diesel engine.

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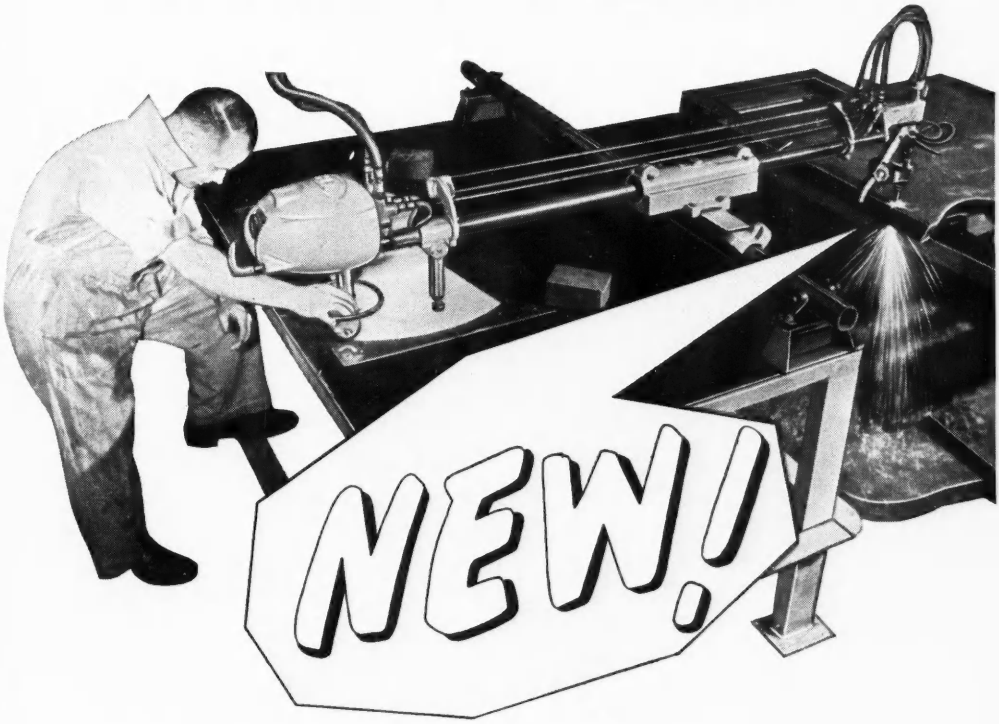

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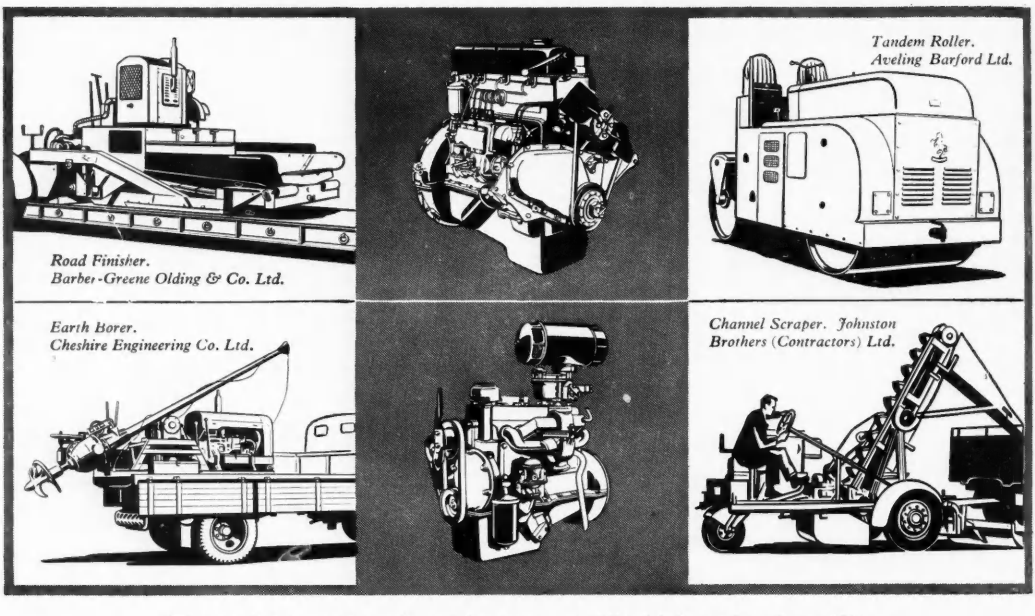

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STROKE MM.	92·5	76·20	76·20	115	115	115	115	115
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1800 ,,	13·75	19·5	30·0	50·0	44·5	—	—	33·0
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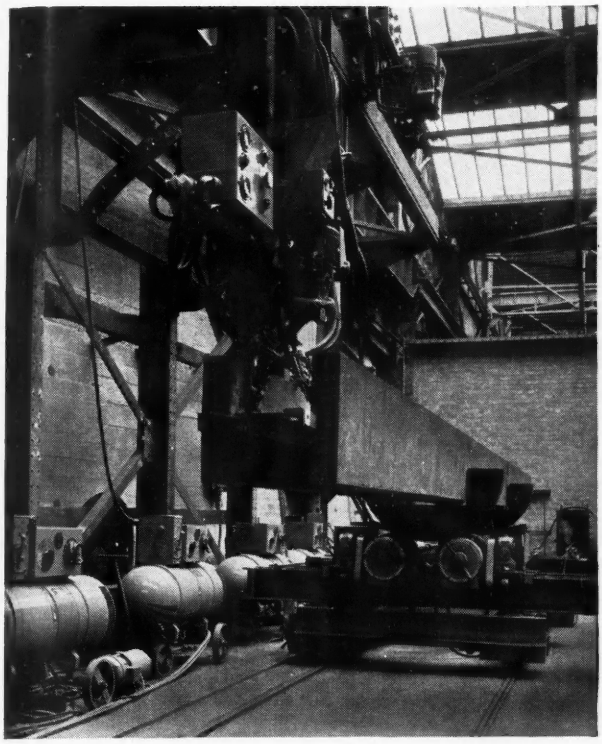

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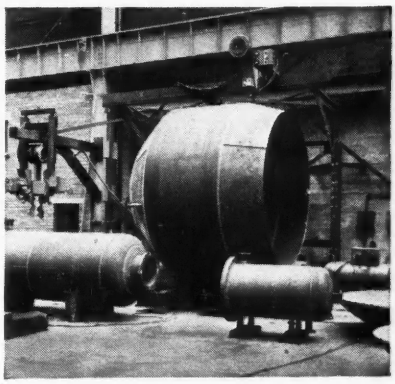
The Lincolnweld process is explained in a brochure available from Dept. C.



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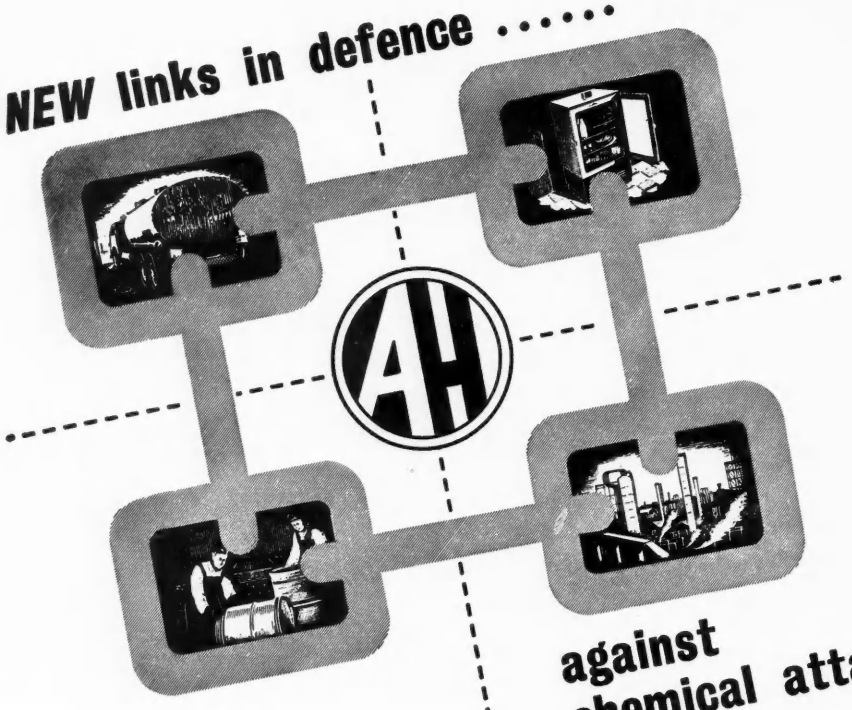

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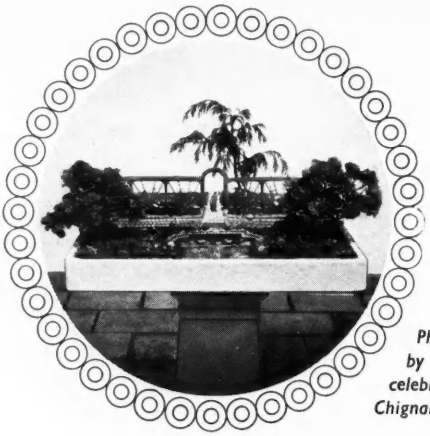

Photograph of Miniature Garden by courtesy of Anne Ashberry, celebrated Miniaturist Gardener of Chignal Smealey, near Chelmsford.

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Who would not be charmed by the miniaturist's garden; with tiny trees, minute roses and other lovely plants, all beautifully proportioned replicas of their larger counterparts, landscaped with lawns, hedges, pergolas, pools and bridges. And the engineer is not slow to appreciate the perfection of Hoffmann ball bearings in miniature — their beautifully finished tracks and balls and their high degree of accuracy. They are made to the well-known Hoffmann limits, and may, if desired, be supplied to finer limits, such as ABEC 3, 5 or 7. They may be used for such diverse purposes as instrument motors, electrocardiographs, pendulum pivots, meters, television cameras, etc.

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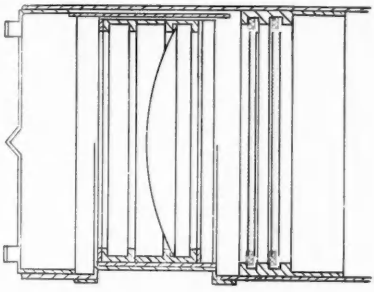
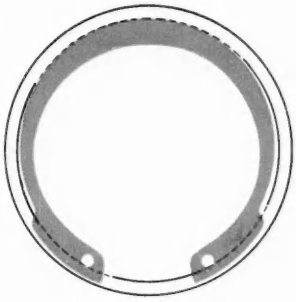


Lenses in a Tube



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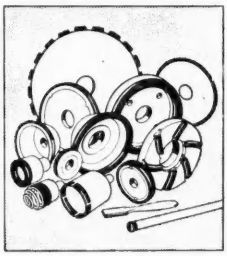

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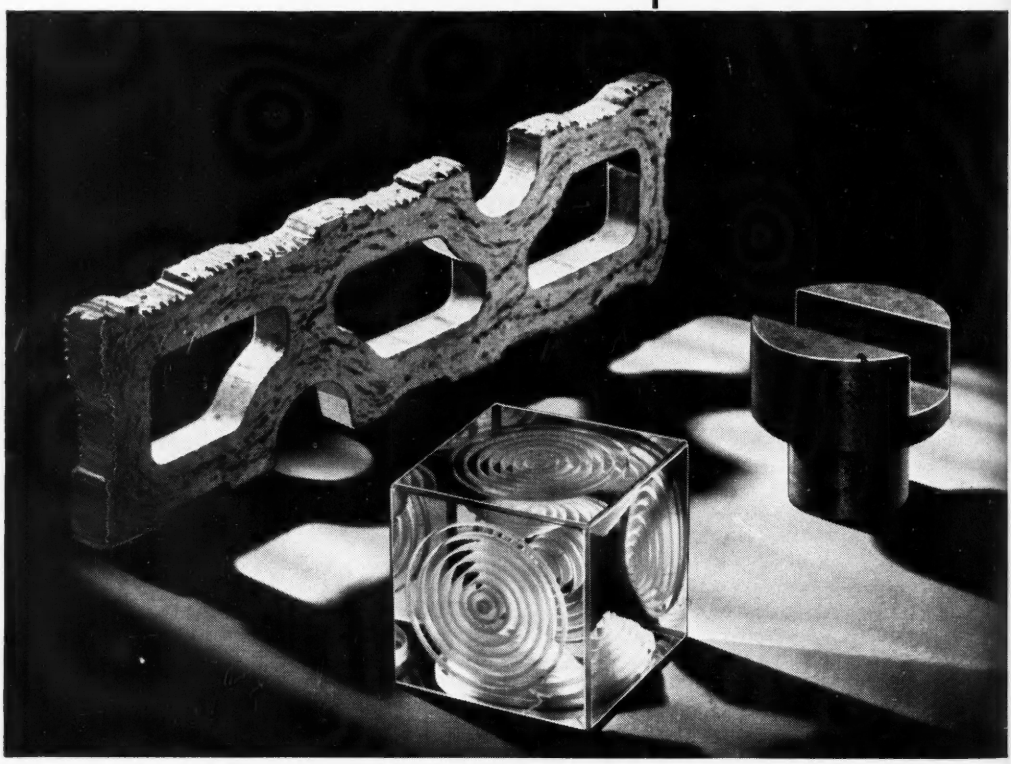

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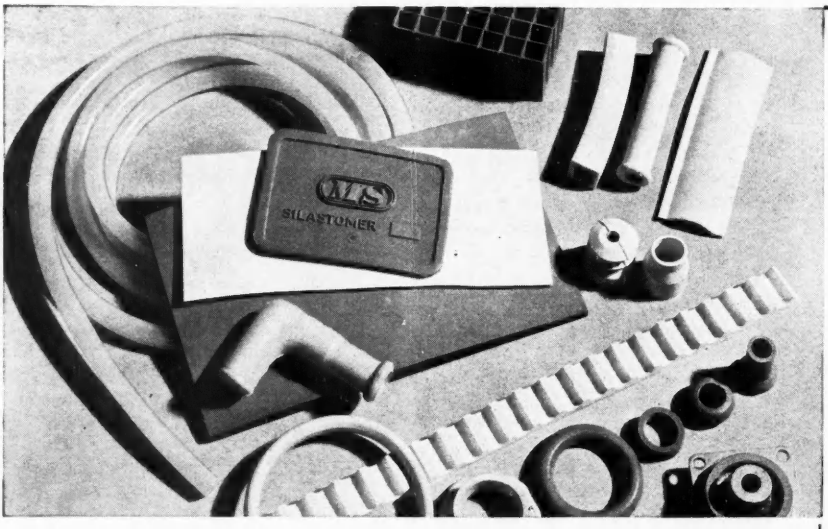

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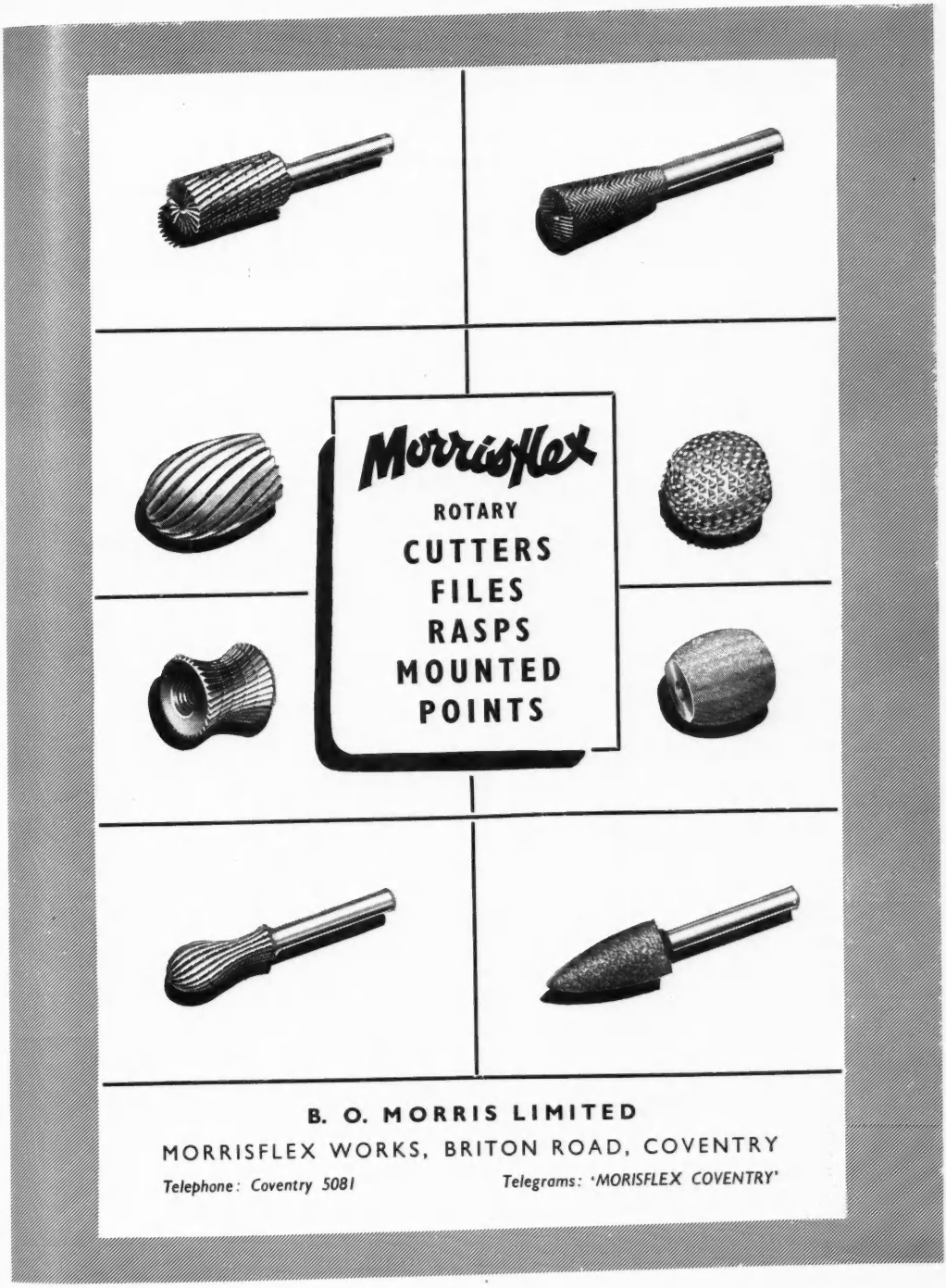

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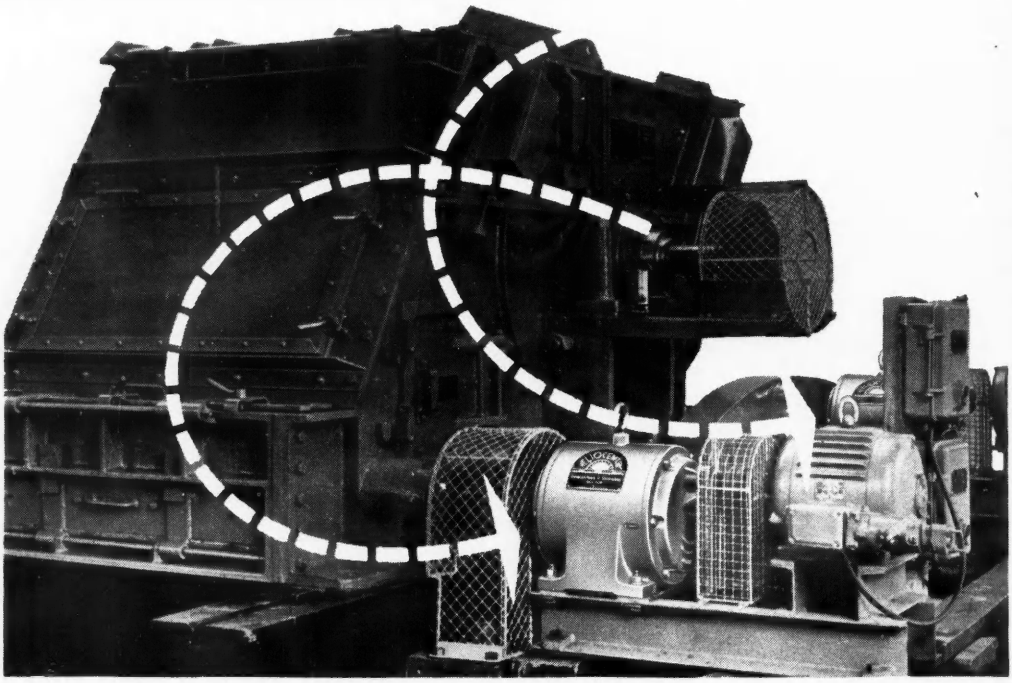

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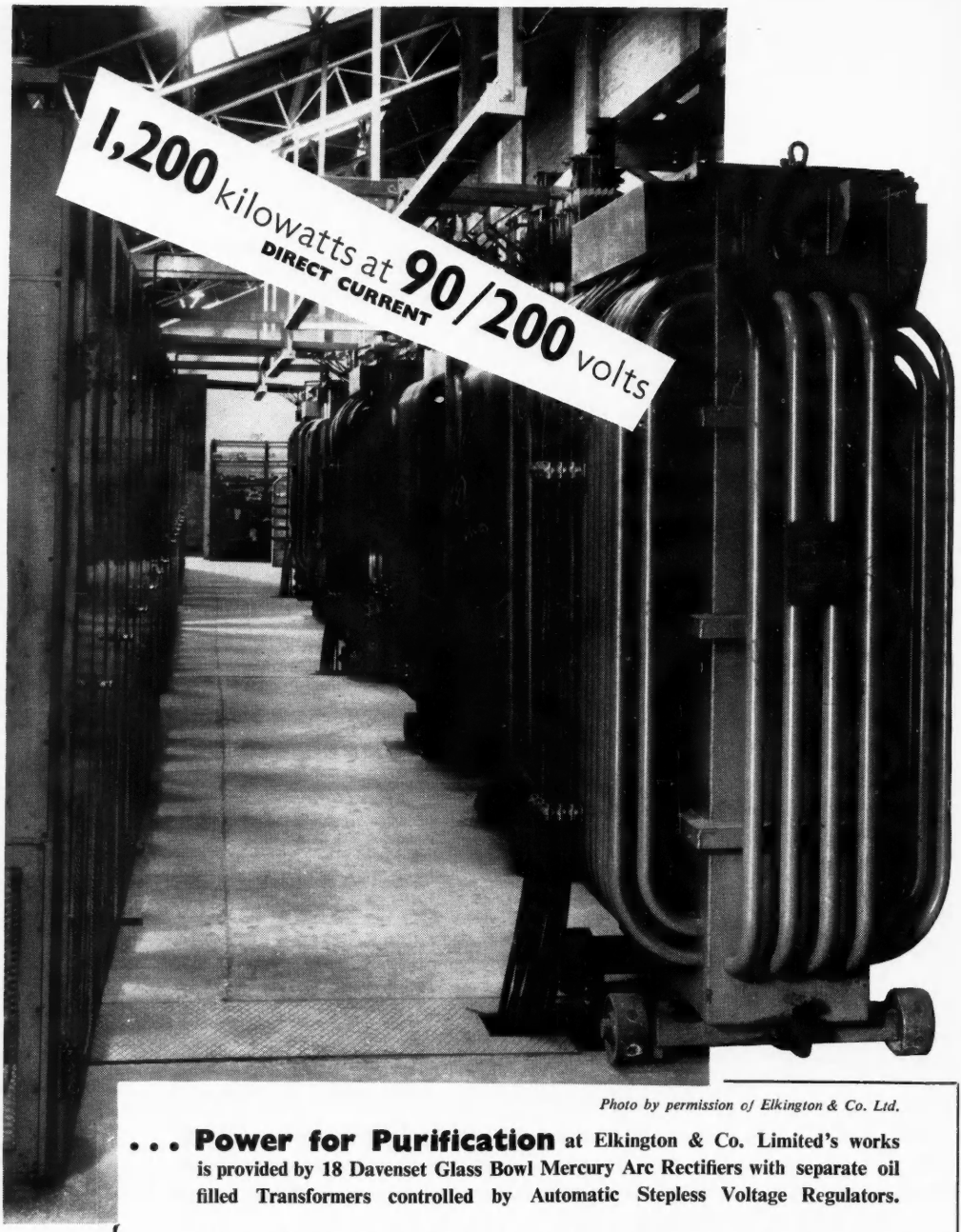

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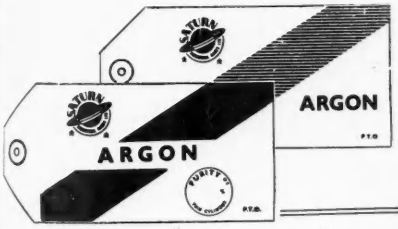

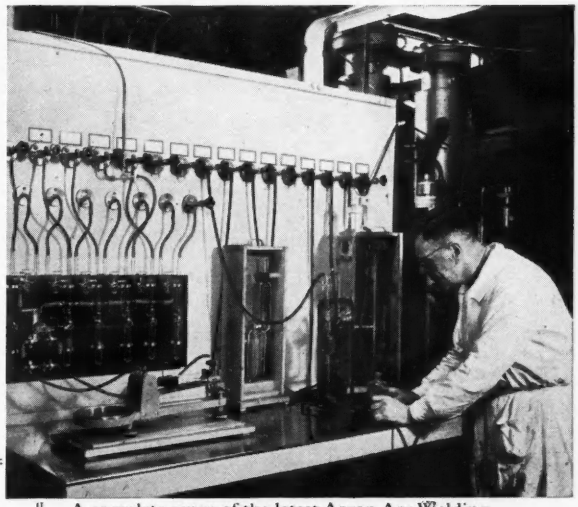

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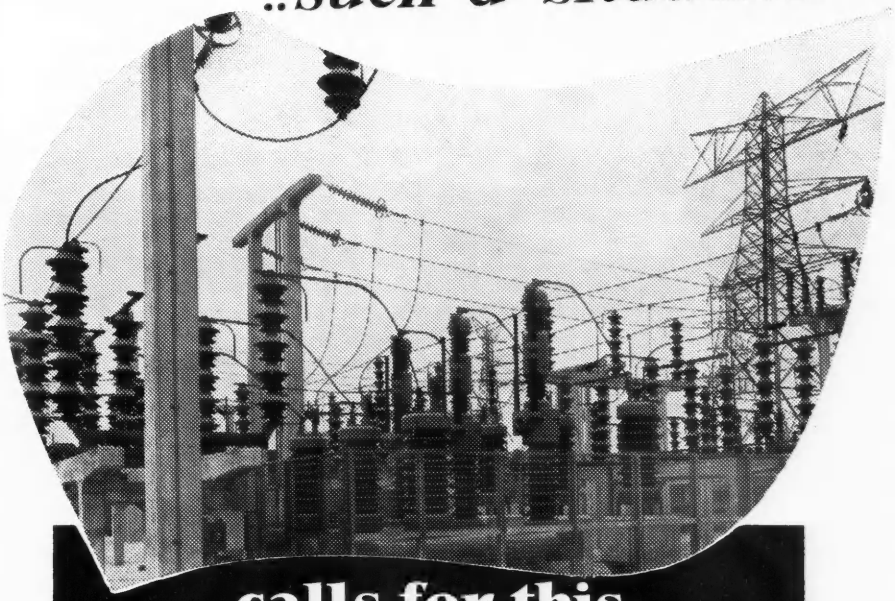

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Thoroughly proven in efficiency, reliability and economy of operation, Miniature Direct Wire remote control systems by *Standard* are serving electricity undertakings at home and overseas, greatly simplifying the central control of electricity generation and distribution networks.

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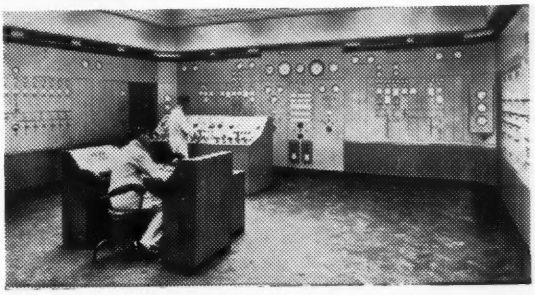

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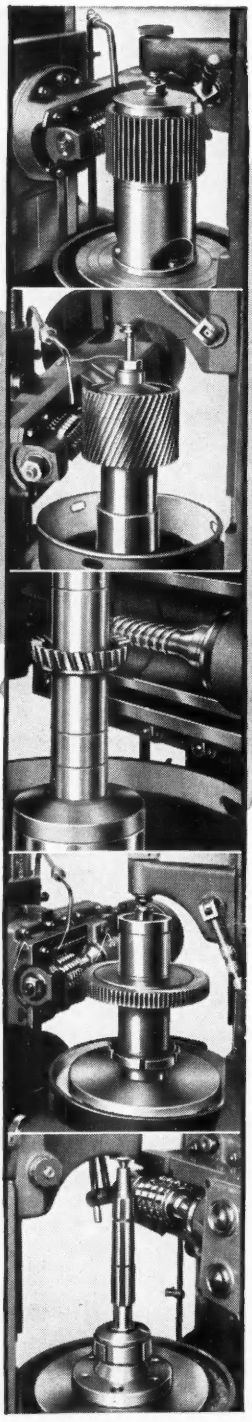
Miniature Direct Wire Remote Control

Standard Telephones and Cables Limited

Registered Office : Connaught House, Aldwych, London, W.C.2

TELEPHONE DIVISION : OAKLEIGH ROAD · NEW SOUTHGATE · LONDON, N.11



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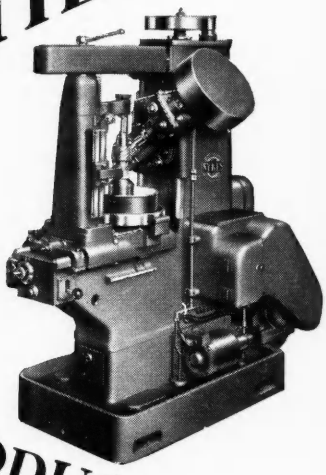

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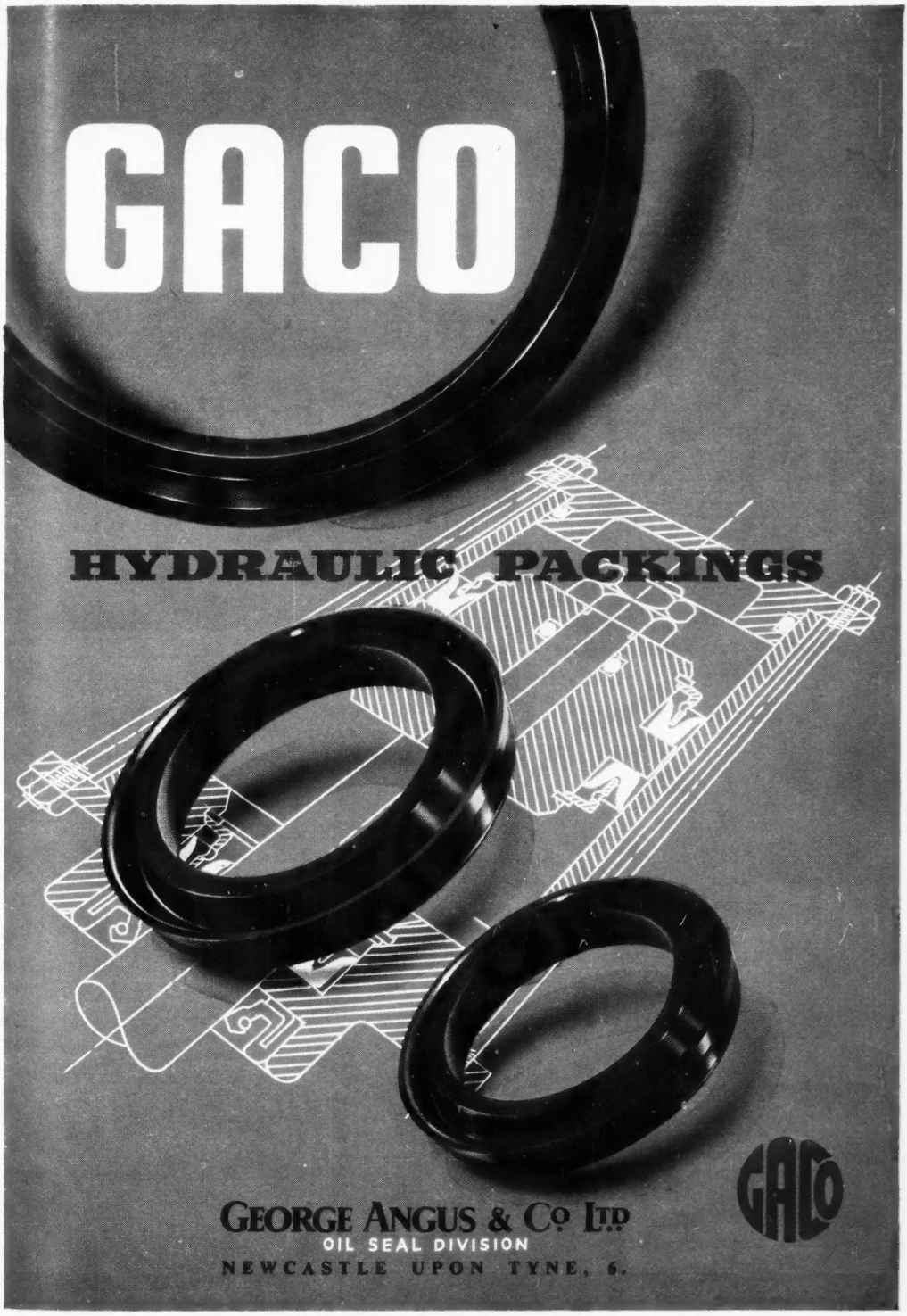
SYKES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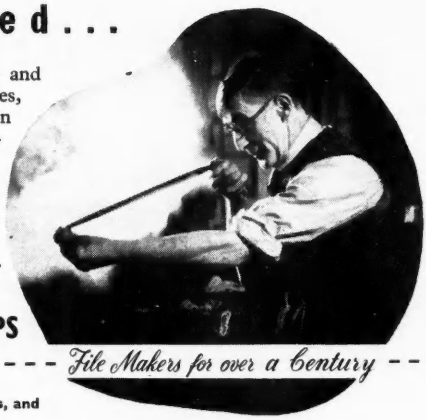

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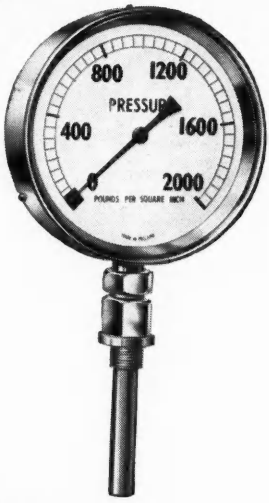

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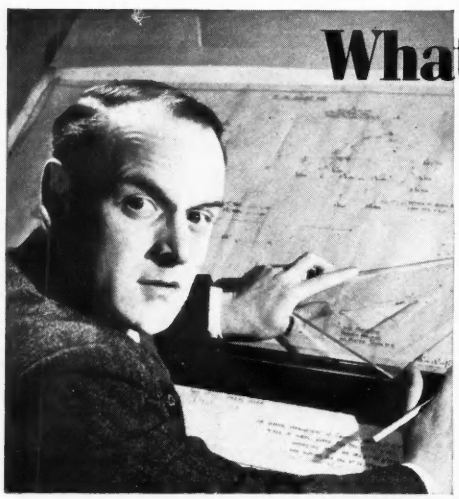

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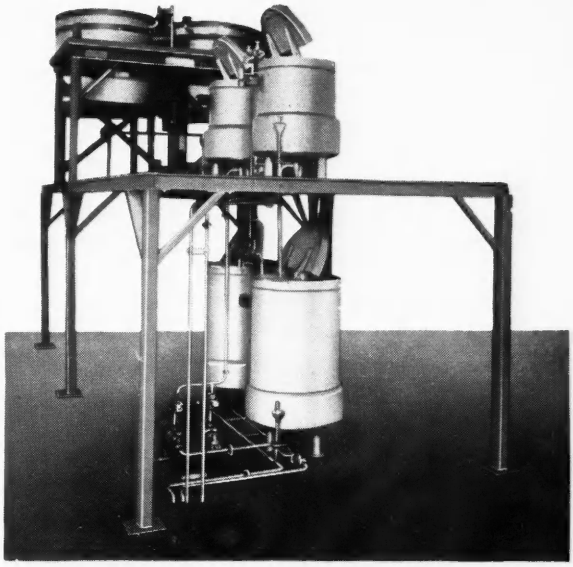

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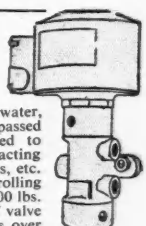

This valve can be used to control air, water, oil and other liquids, normally passed through a pipe where it is required to operate Diaphragm Valves, single acting and double acting cylinder mechanisms, etc. Standard valves are suitable for controlling pressures up to 70 lbs. per sq. in. or 100 lbs. per sq. in. as required. This type of valve is capable of operating at high speeds over long periods.

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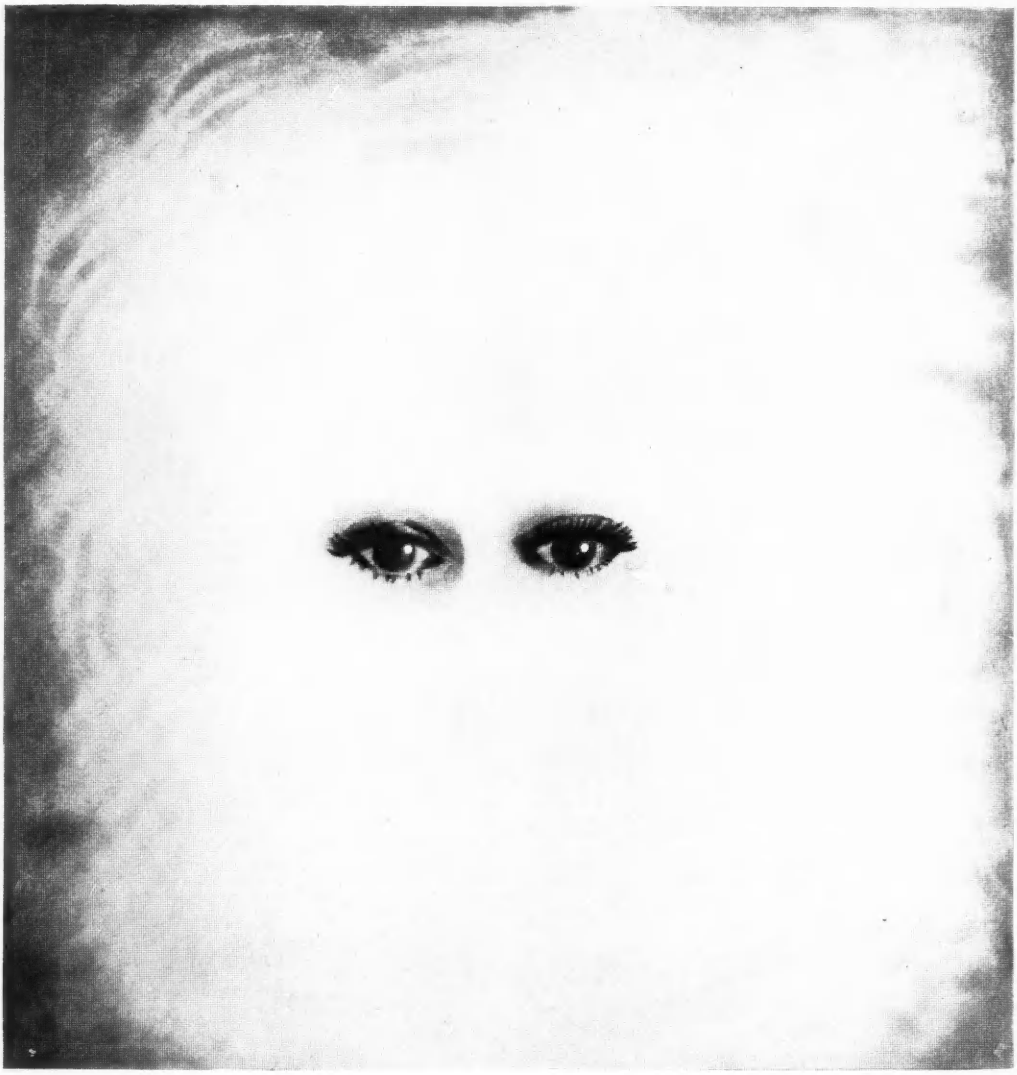

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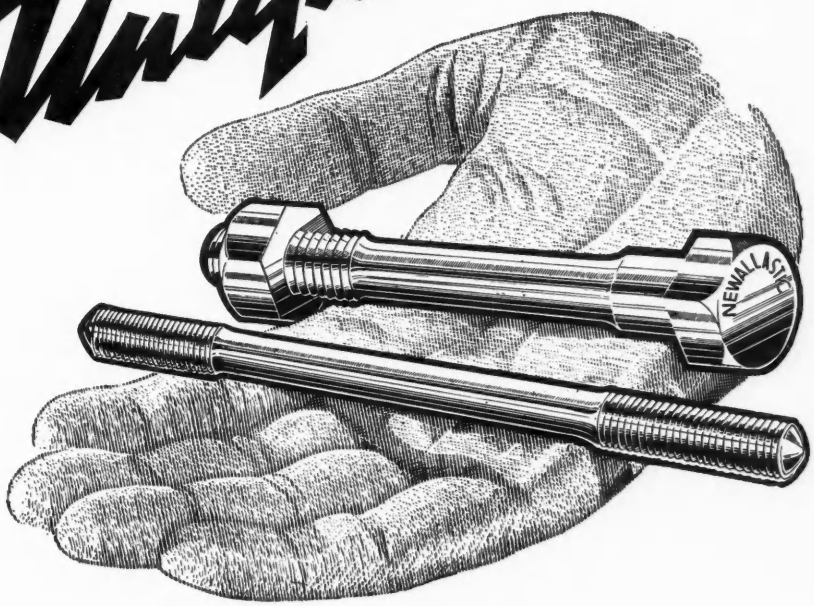

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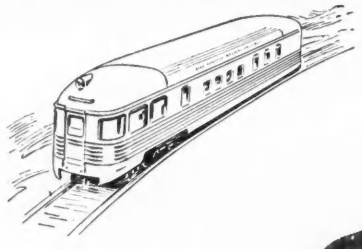

Consolidation of core laminations and assembling locking ring; Forcing Shaft into core; Assembly of Rotor Unit. All operations requiring a Hydraulic Press.

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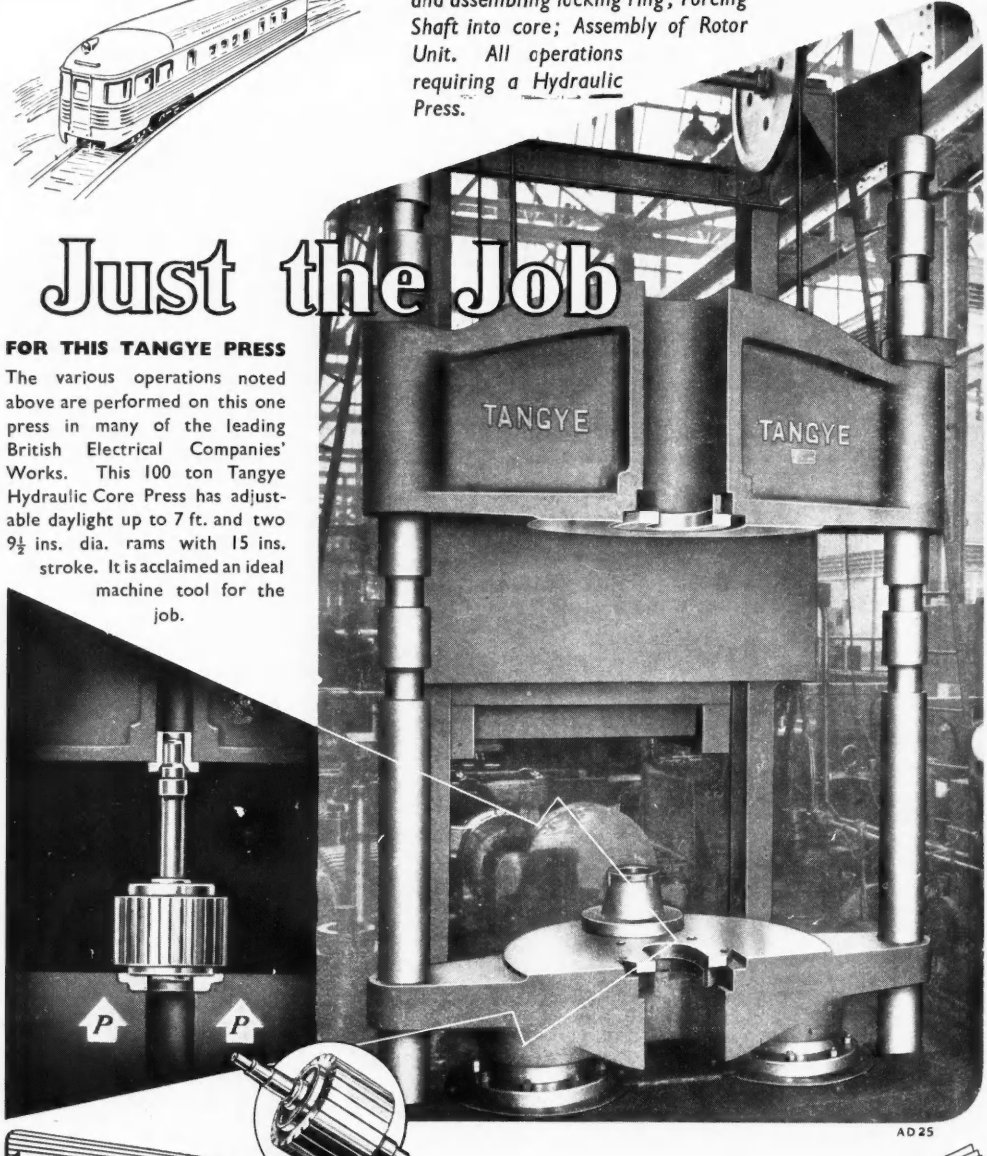
The various operations noted above are performed on this one press in many of the leading British Electrical Companies' Works. This 100 ton Tangye Hydraulic Core Press has adjustable daylight up to 7 ft. and two 9½ ins. dia. rams with 15 ins. stroke. It is acclaimed an ideal machine tool for the job.



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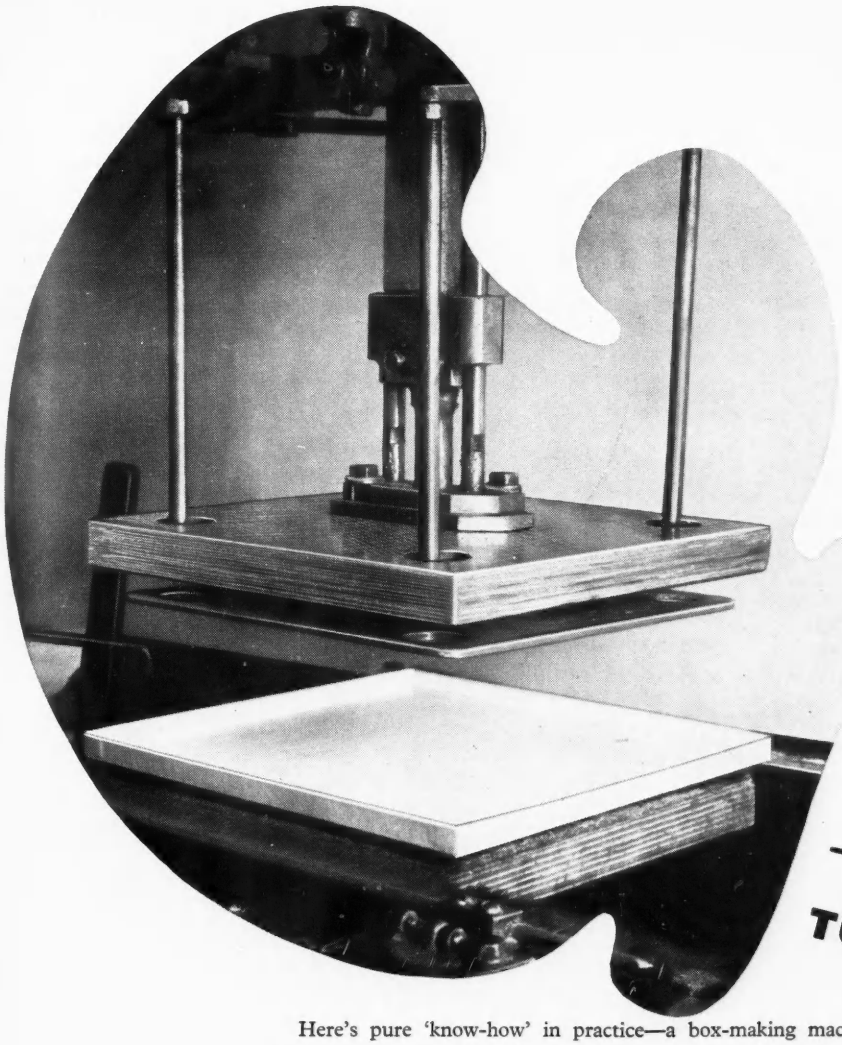

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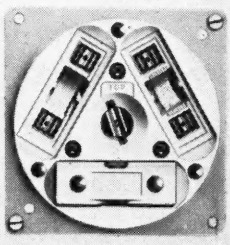
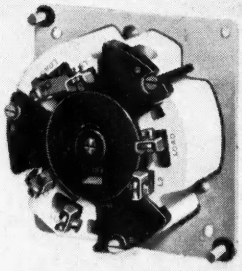
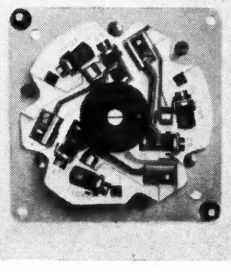
Attractively designed cover and cast iron case of the MEM Rotary Fused Isolator are finished in grey stove enamel.



Fuse inspection [illegible] absolutely safe. The fuse sockets are [illegible] lated by the remov of the cover and it impossible to touc live metal.



Wiring is especial easy. Heavy clam terminals are pro vided and are clear identified. An indi cator shows whether the switch is on o off.



The three phases o the robust cas operated switch are separated by thick porcelain walls. Contacts are solid silver. Inspection i simple once the plastic switch cover is removed.

Handsome appearance and high efficiency go hand in hand here, in the MEM Rotary Fused Isolator.

Designed for use with A.C. Motors on machine tools and other similar applications, this switch is of a slow break A.C. pattern rated at 15 amps., 500 volts. It will safely disconnect a stalled motor of 7½ h.p. taking six to eight times full load current.

The unit takes 15 amp., rewirable " Kantark Major " fuses or alternatively you can choose standard H.R.C. fuse links to the dimensions of B.S.88 1952, Appendix J.

Fuses can be inspected or renewed in perfect safety. The cover can only be removed when the switch is in the ' off ' position, and then the fuse contacts are completely isolated from the incoming supply.

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MEM

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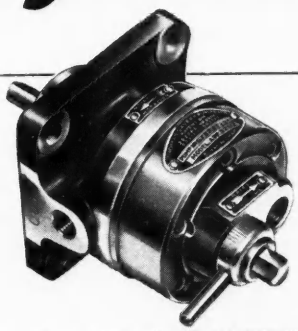
Hydraulic Pumps



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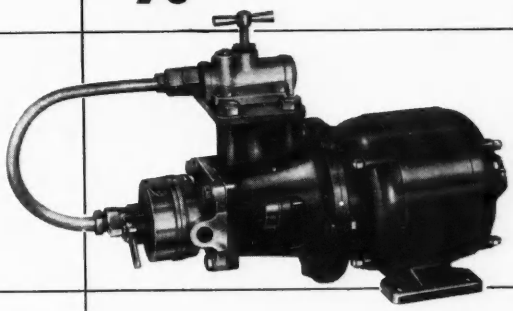

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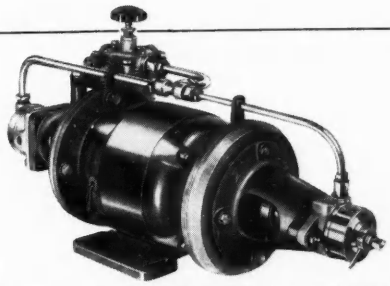

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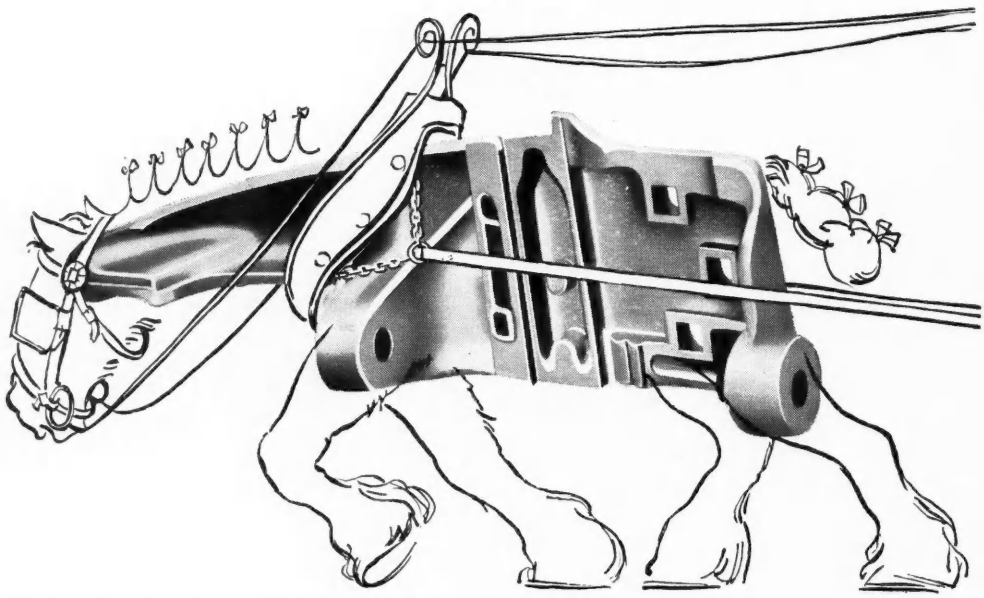

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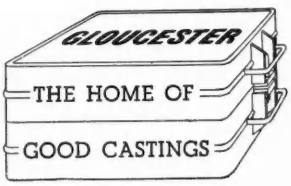
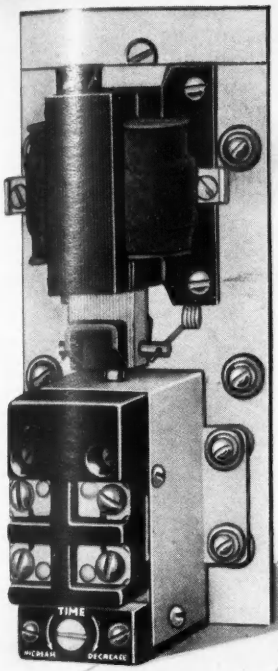
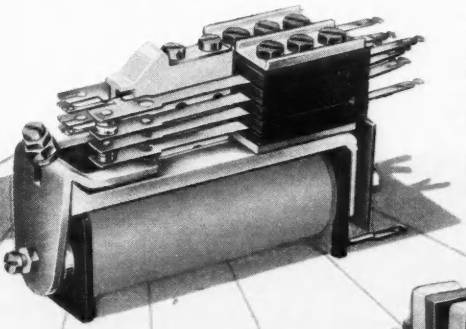
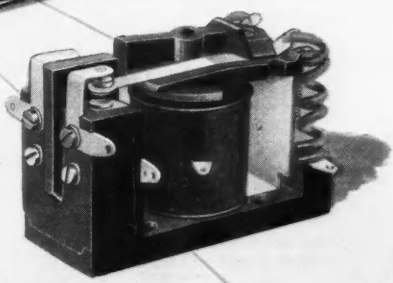
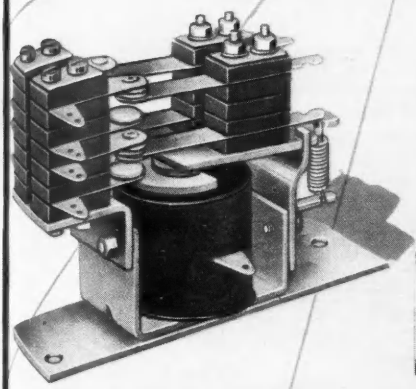


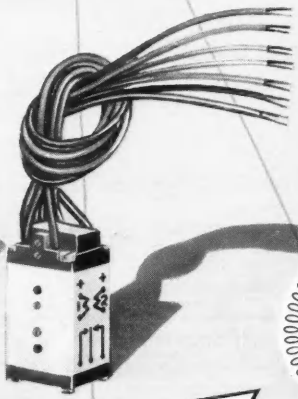
Precision Relays











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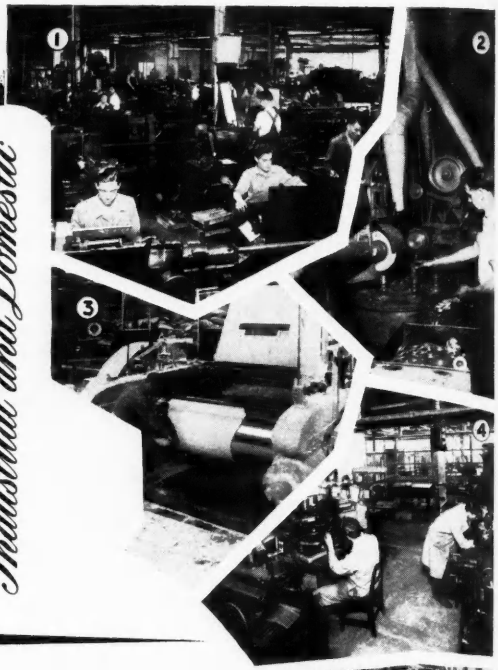

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4. View of development department.
5. Side view of electro-plating conveyor.
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7. Enamelling conveyor, spraying booths and infra-red drying tunnel oven.
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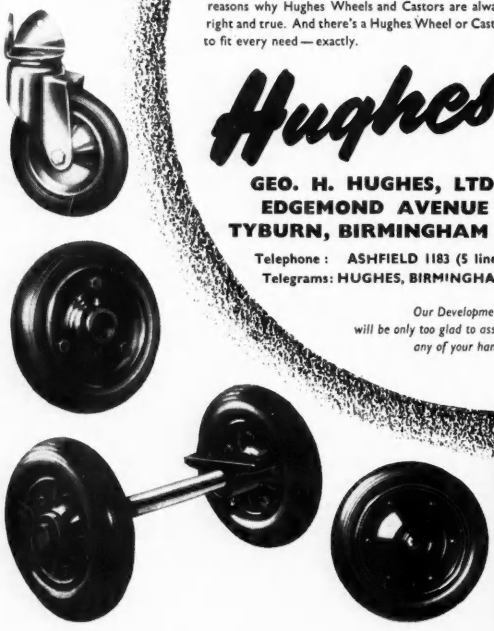

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The world's most widely used combination electrical measuring instrument. It provides 50 ranges of readings on a 5-inch hand calibrated scale fitted with an anti-parallax mirror, and is guaranteed accurate to B.S. first-grade limits on D.C. and A.C. from 25c/s to 2 Kc/s. The movement is effectively damped to facilitate reading. The meter will differentiate between A.C. and D.C. supply, the switching being electrically interlocked. The total resistance of the meter is 500,000 ohms. The instrument is self-contained, compact and portable, and is protected by an **automatic cut-out** against damage through inadvertent application of overload. Power Factor and Power can be measured in A.C. circuits by means of an external accessory (the Universal AvoMeter Power Factor and Wattage Unit).

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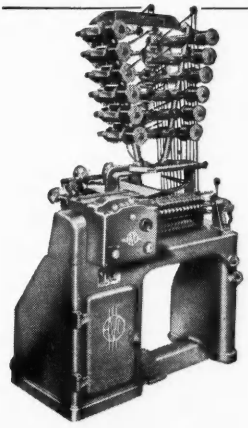

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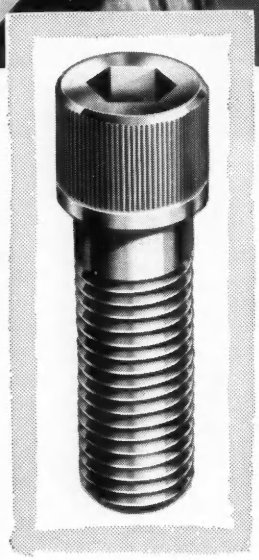

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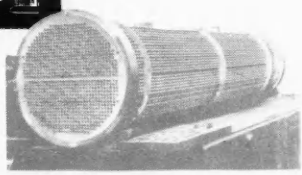

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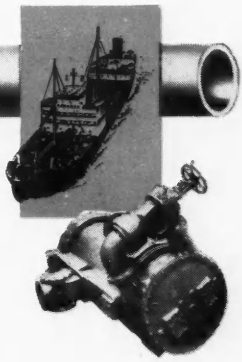

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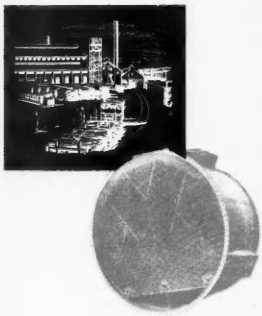

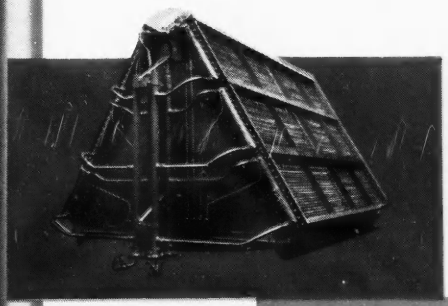

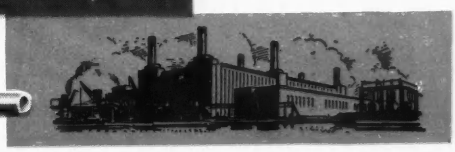

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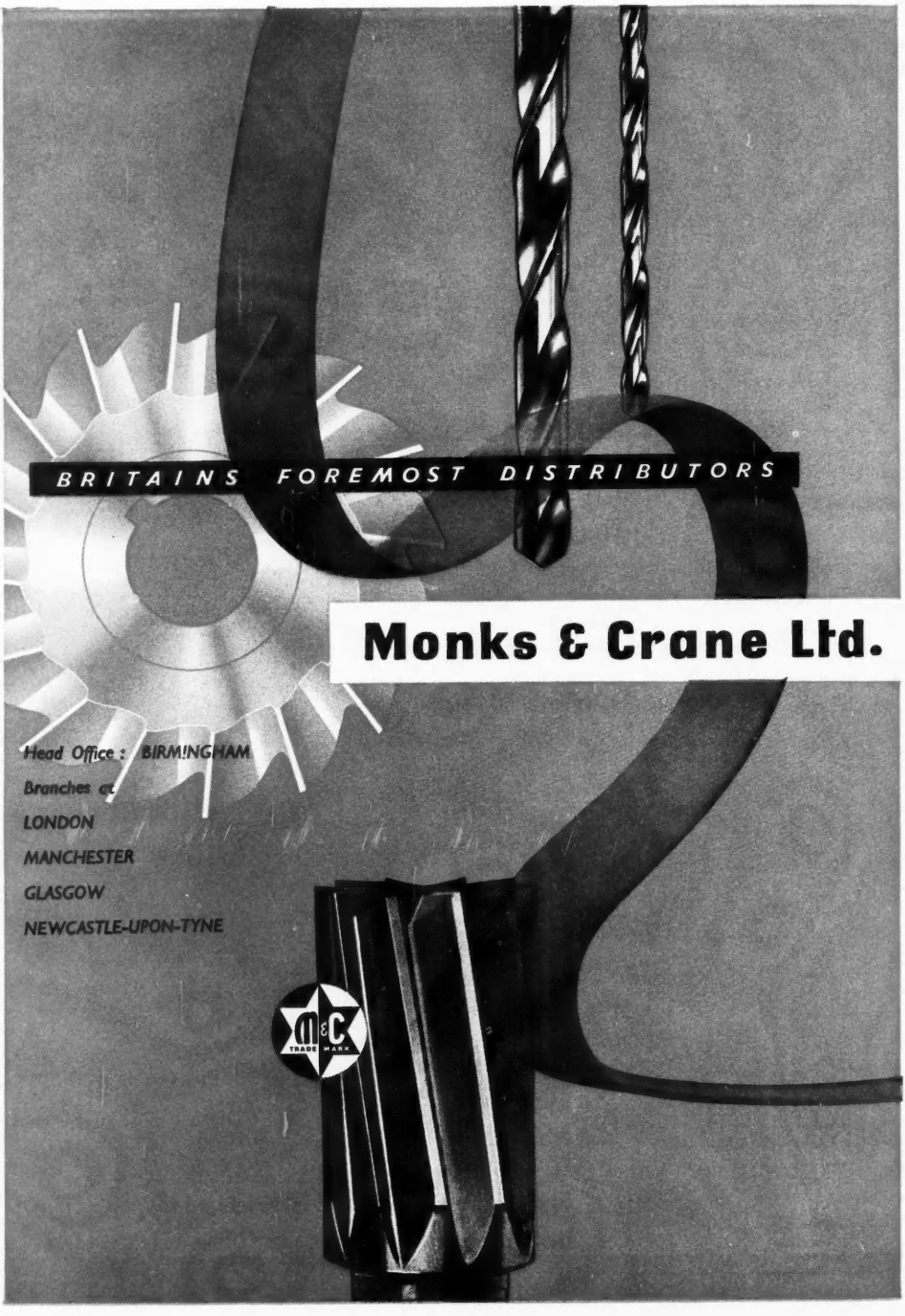
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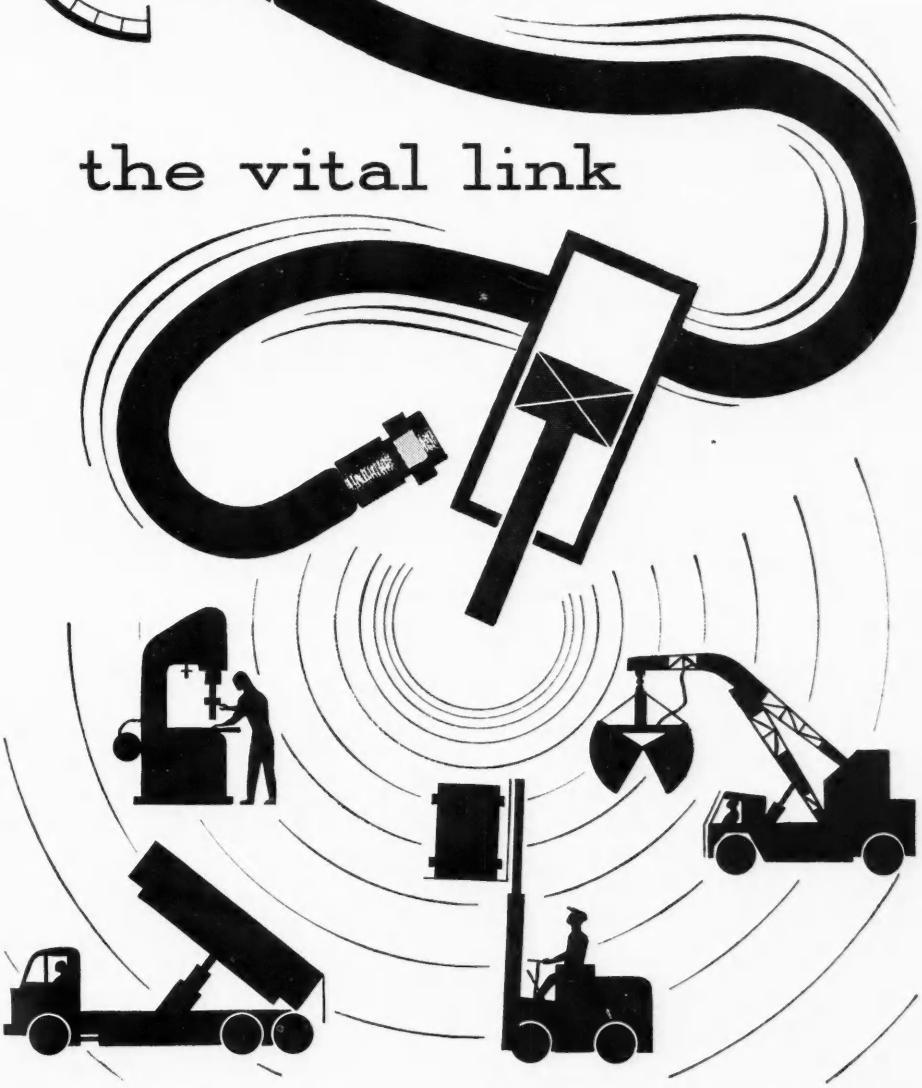

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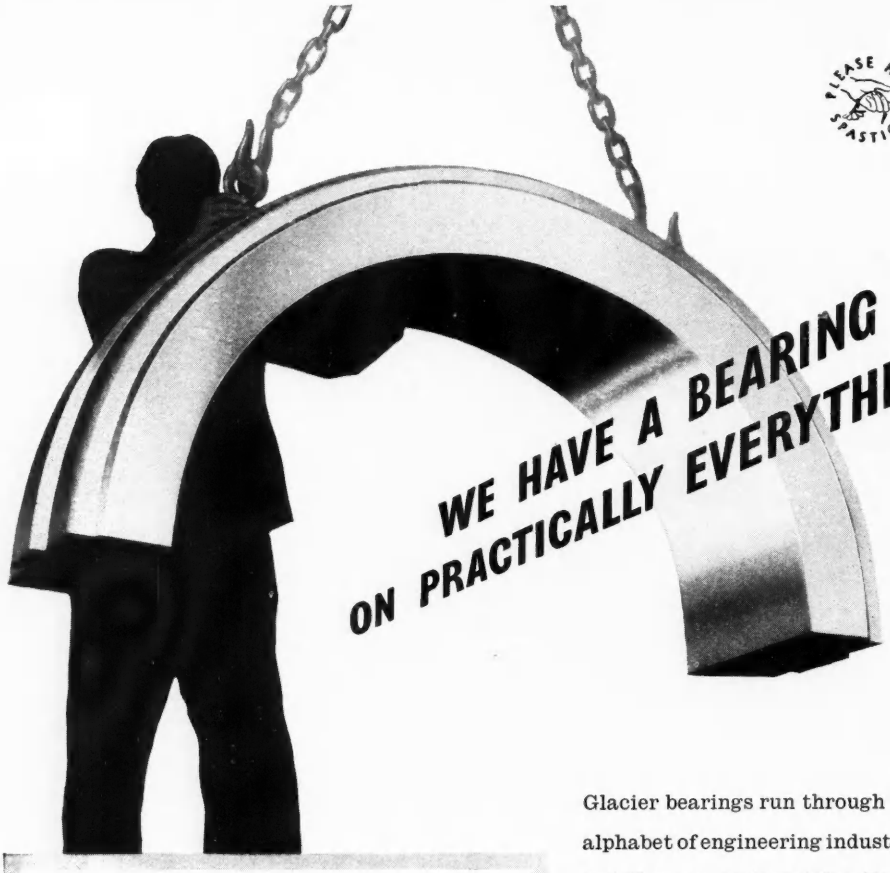

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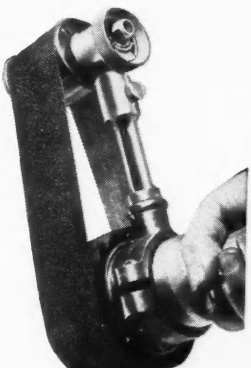

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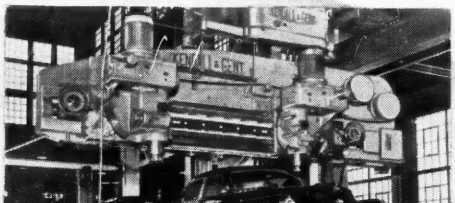

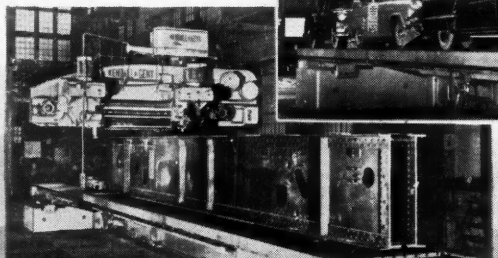

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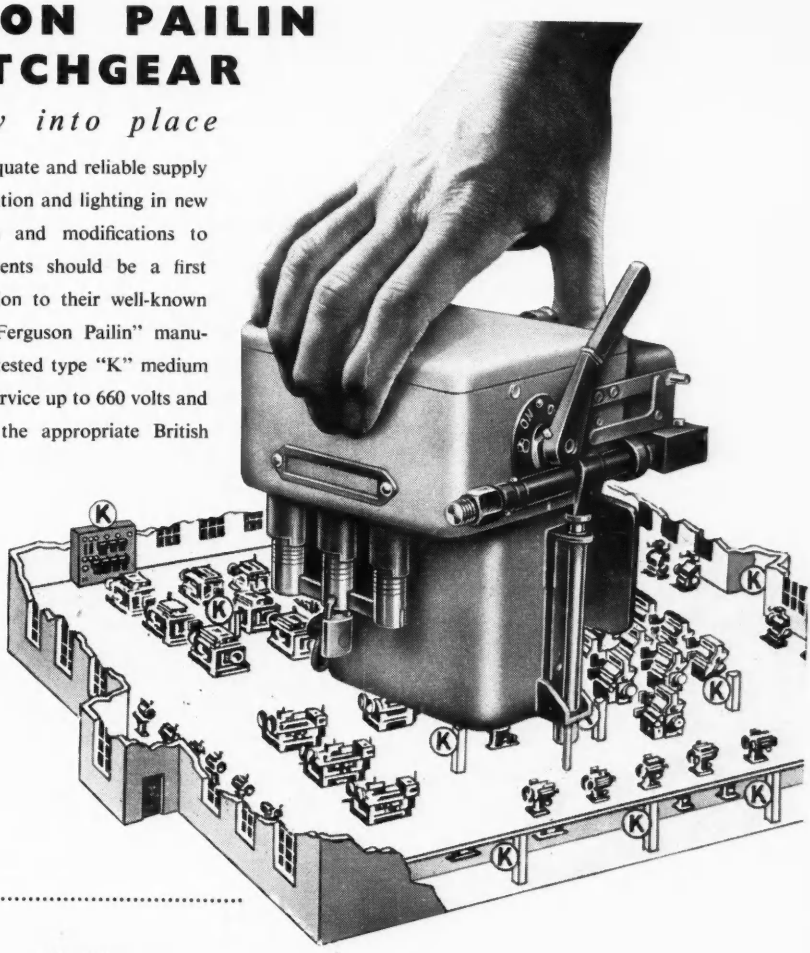

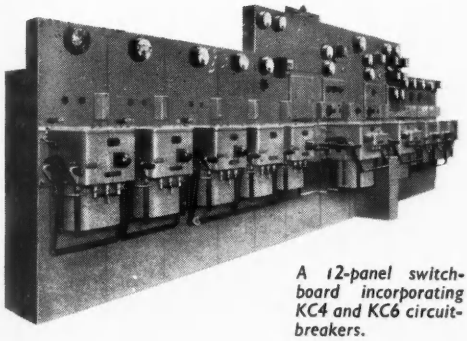

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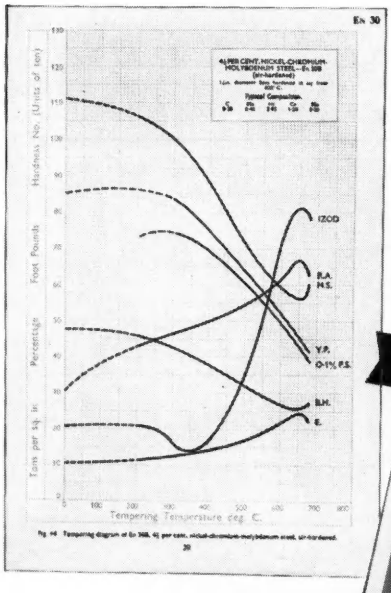

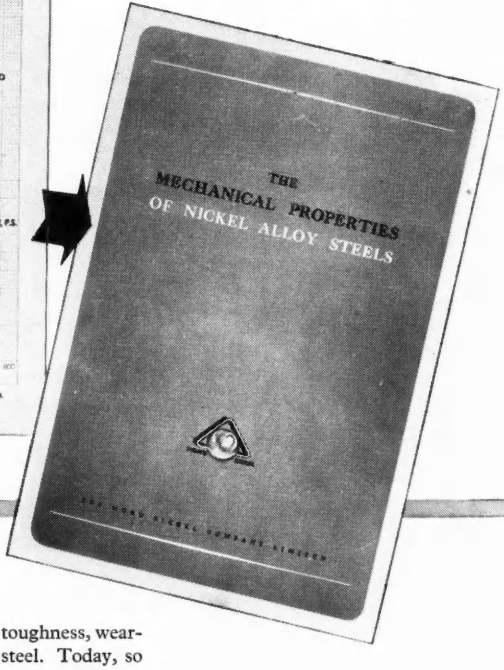

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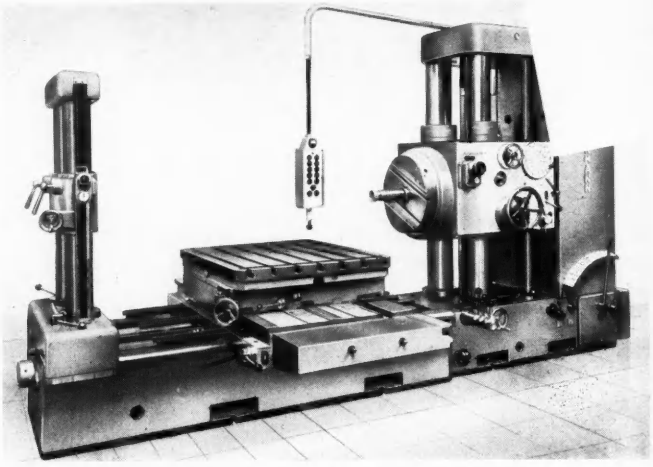

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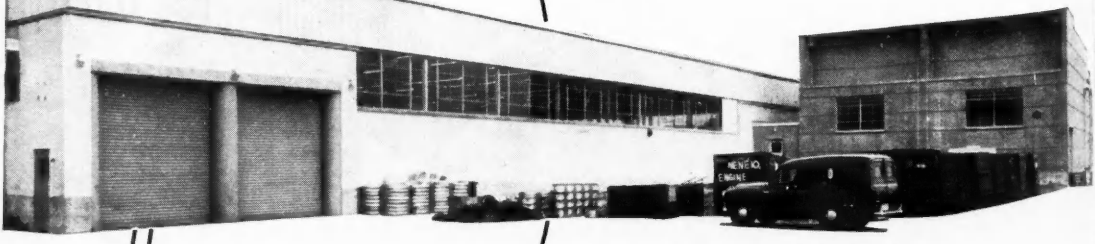

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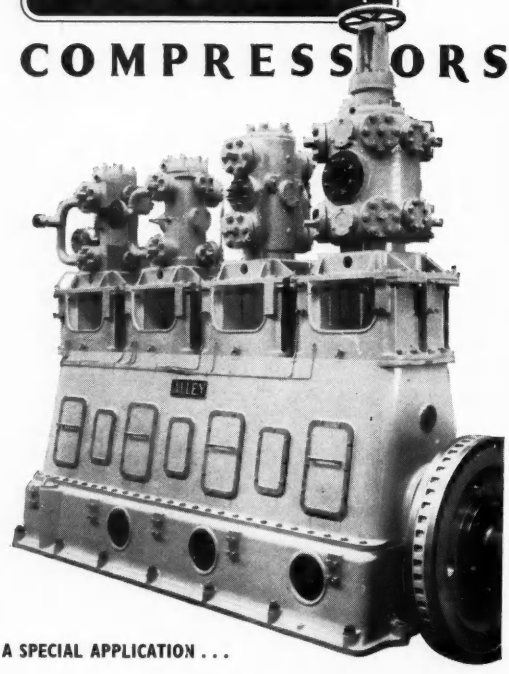

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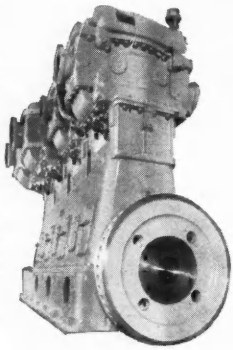

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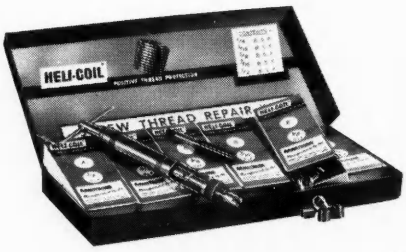

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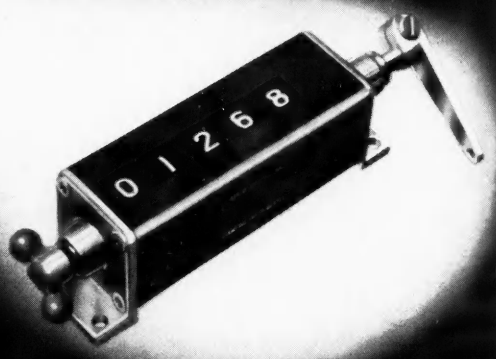

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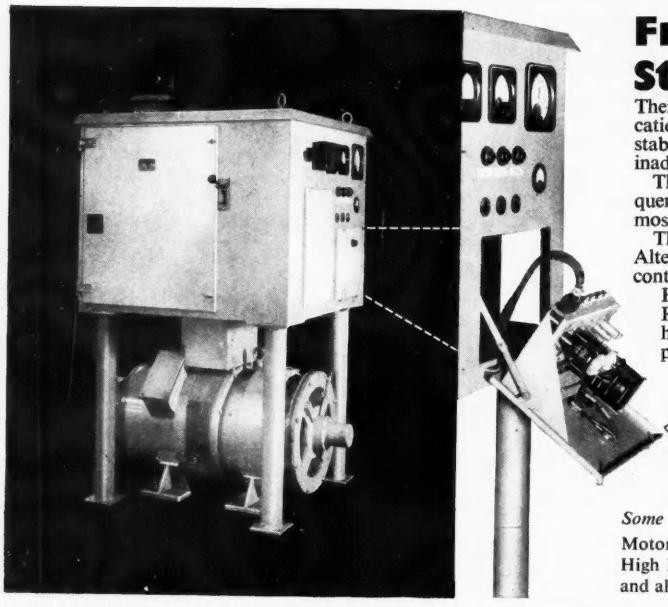

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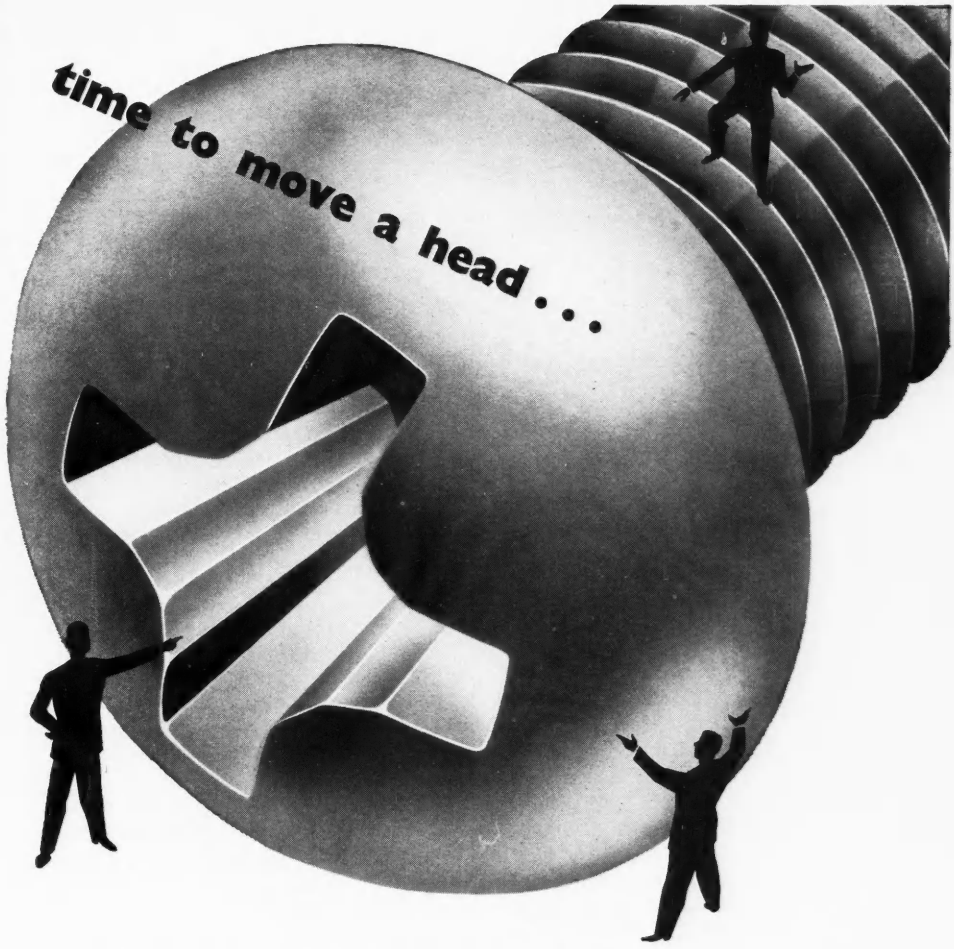

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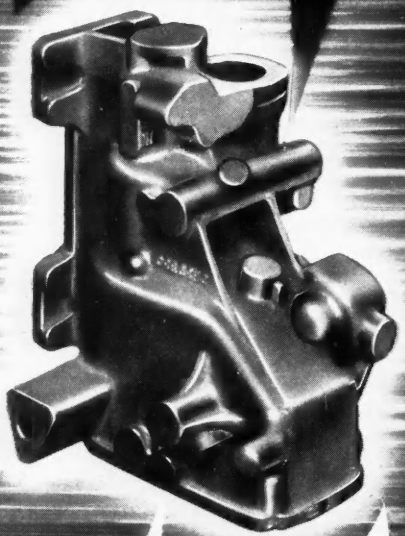

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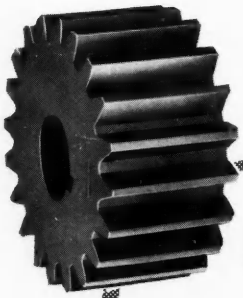

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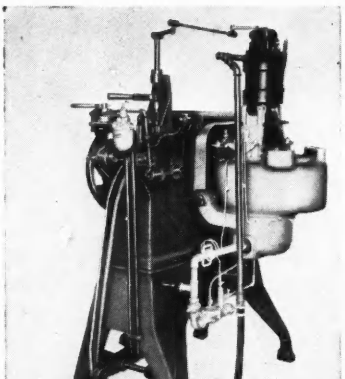

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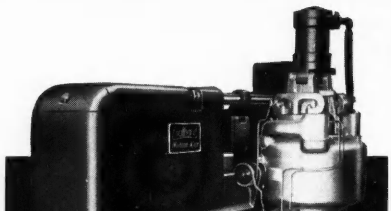

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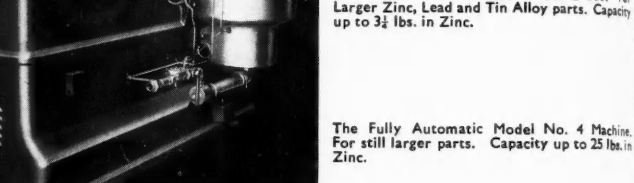

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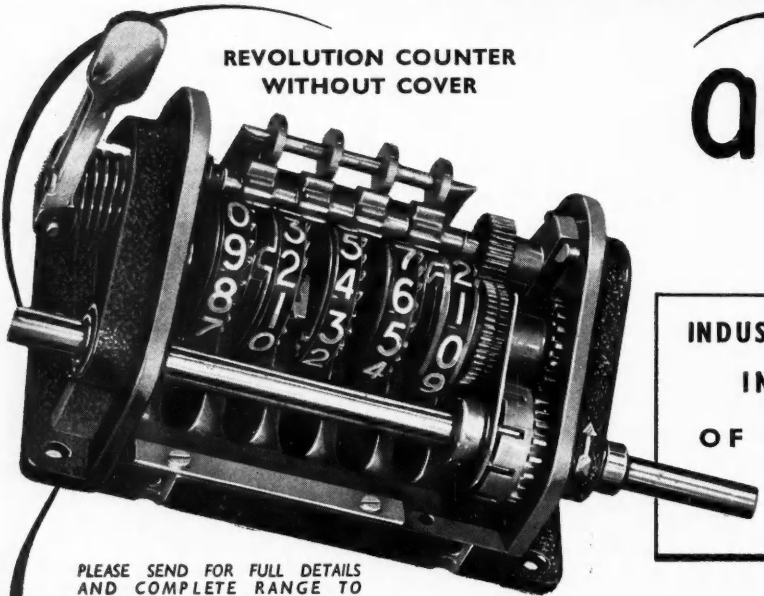

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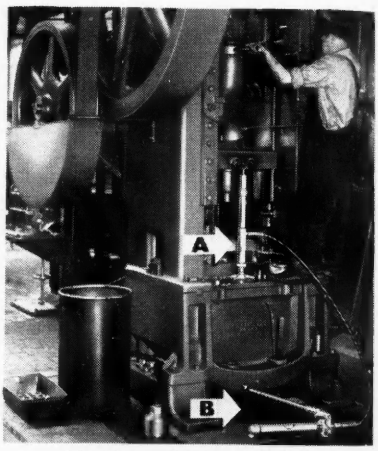

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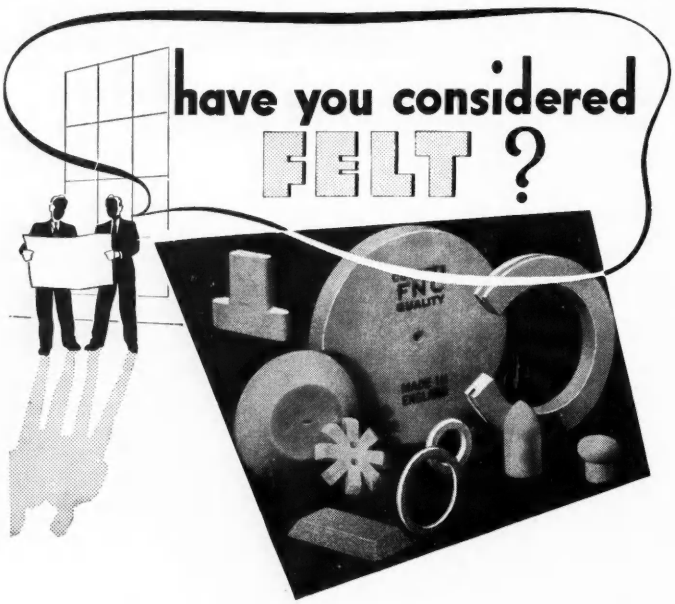

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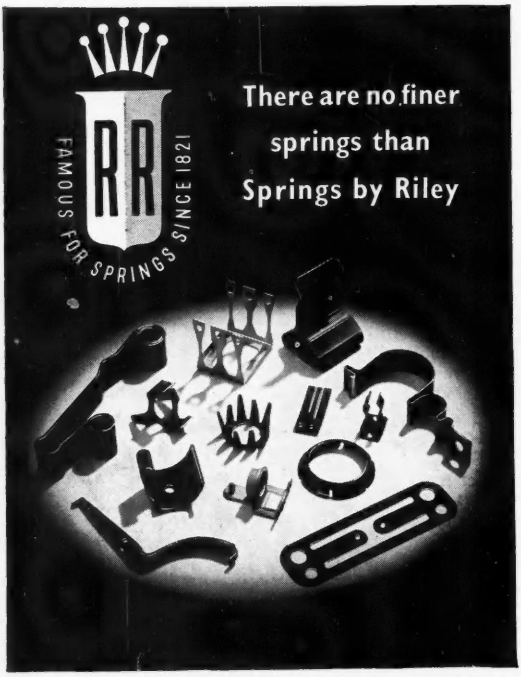

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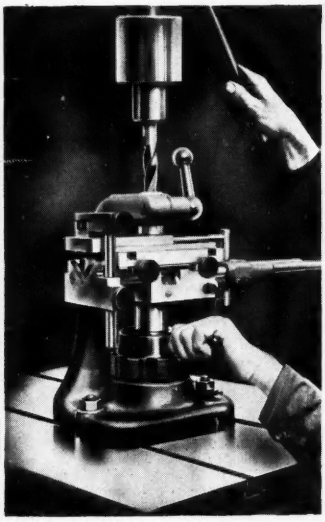

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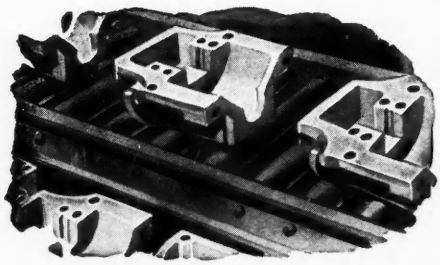

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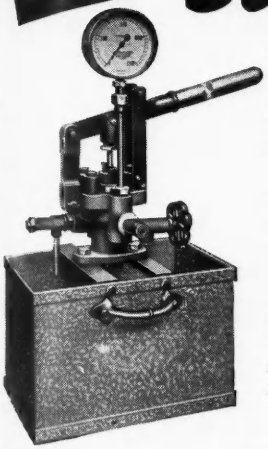

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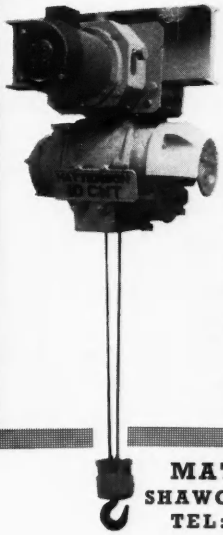

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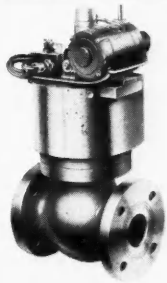

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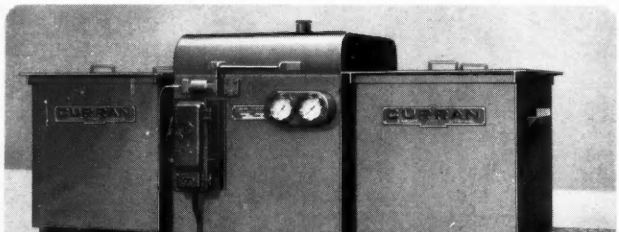

This latest addition to the vast range of Curran Industrial Cleaning Units has an entirely new process of degreasing metal parts prior to plating, phosphating and other surface treatment. It has great advantages over the conventional vapour degreasing and is speedy, reliable and relatively cheap. Polishing Compounds, Lapping Compounds, Water Soluble Oils, Soaps and Organic Contaminants disappear like magic. Write today for full details of this unique degreaser.

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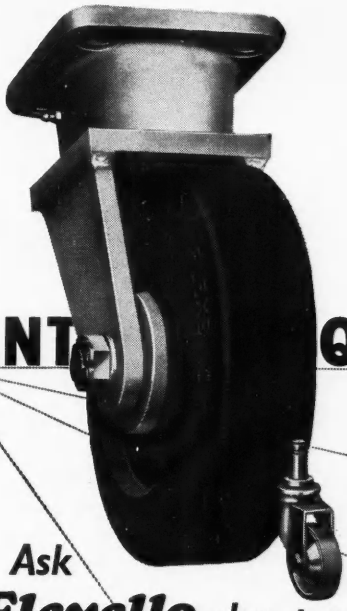

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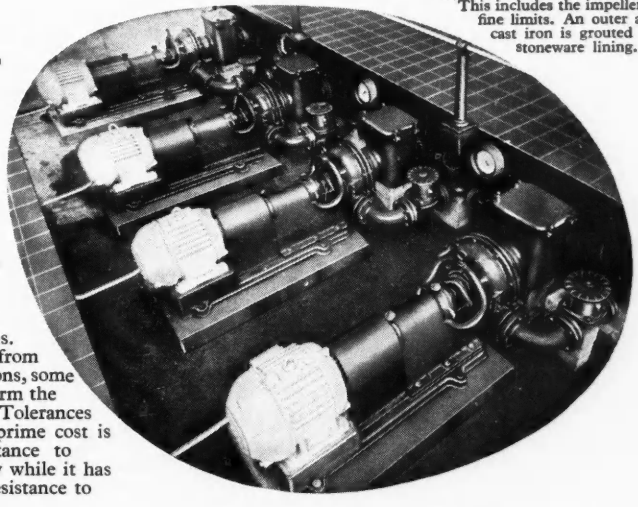

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Hathernware Stoneware is ideal for the movement of corrosive liquors and gases. It is inert to all chemical attack except from hydrofluorics and, under certain conditions, some hot caustics. It can be machined to form the precision moving parts of mechanisms. Tolerances of 0.05 m/m can be maintained. Its prime cost is below other materials offering resistance to corrosion, its maintenance factor is low while it has high compressive strength and great resistance to abrasion.

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Industrial Ceramic Engineers.

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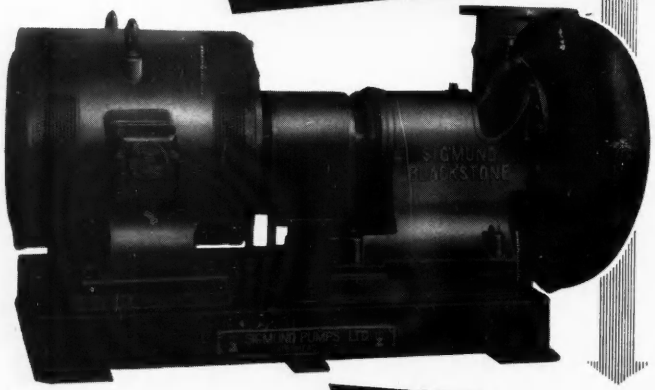

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HIGH SPEED MULTIPLE DISC CLUTCHES

Powerful, clean in contour and ideally suitable for machine tool drives, etc., these clutches do not need frequent adjustment.

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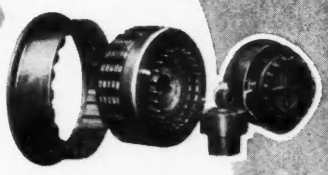

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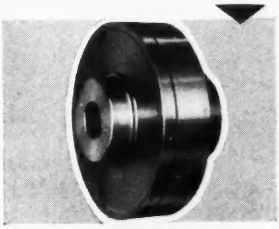

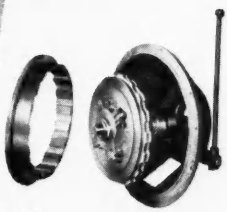

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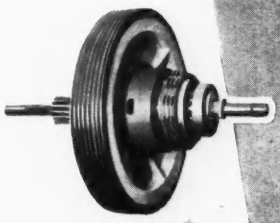

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Suitable for presses, shearing machines, forging machines, and other heavy duty drives.

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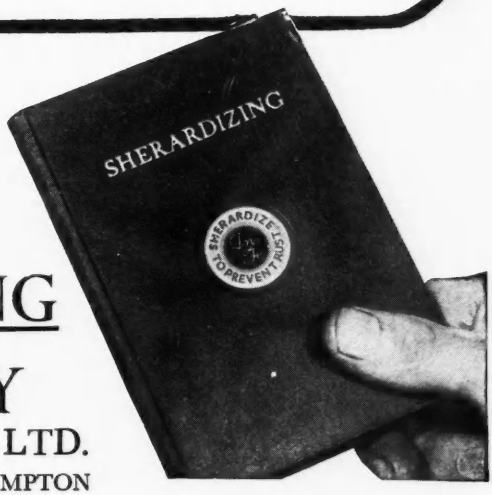

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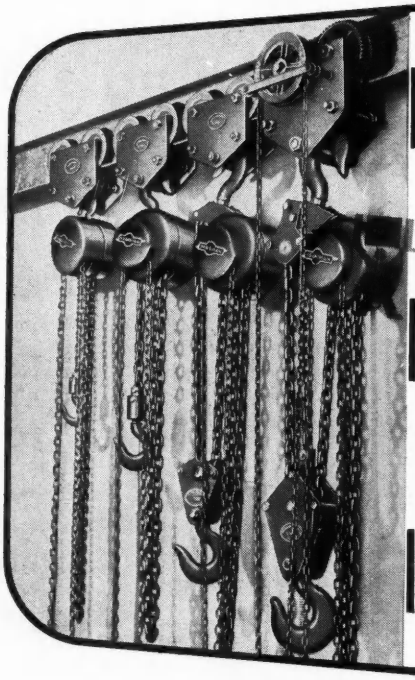

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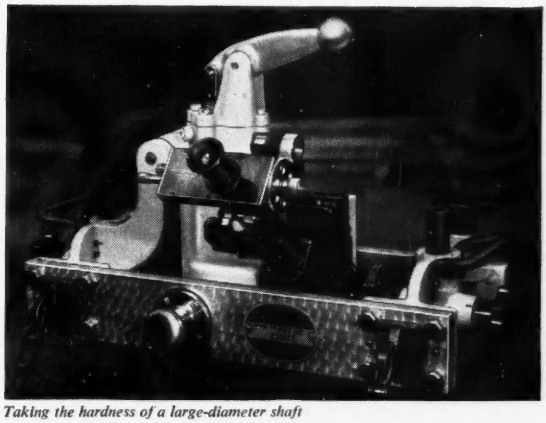

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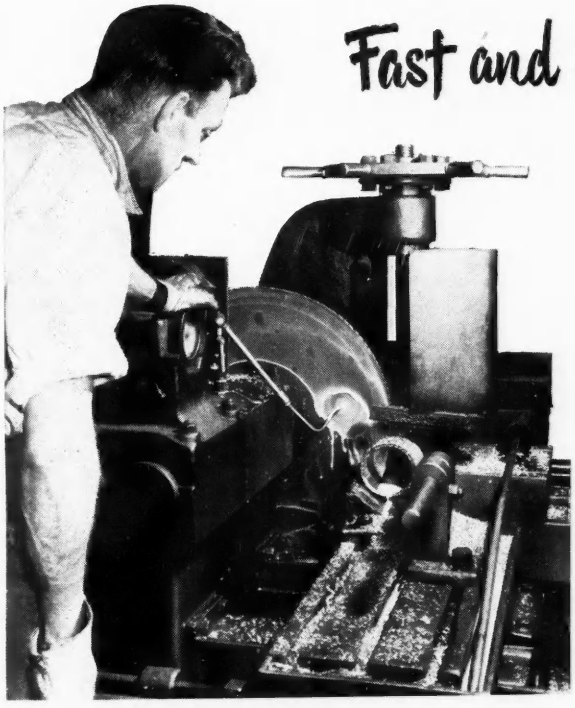

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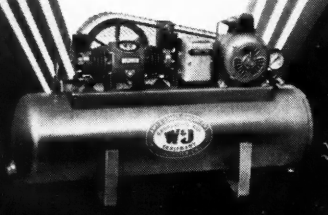

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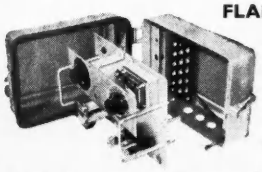

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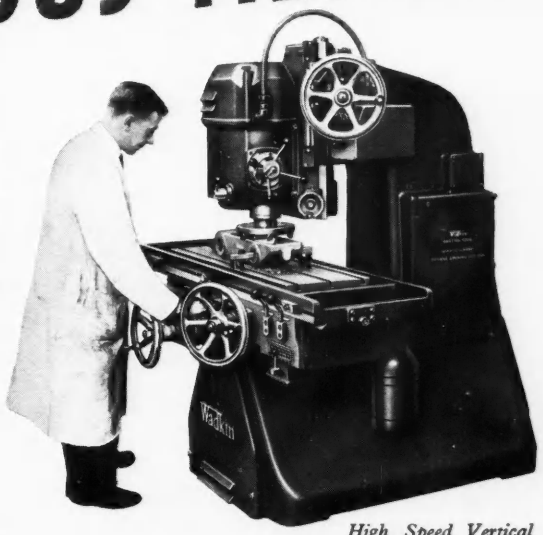

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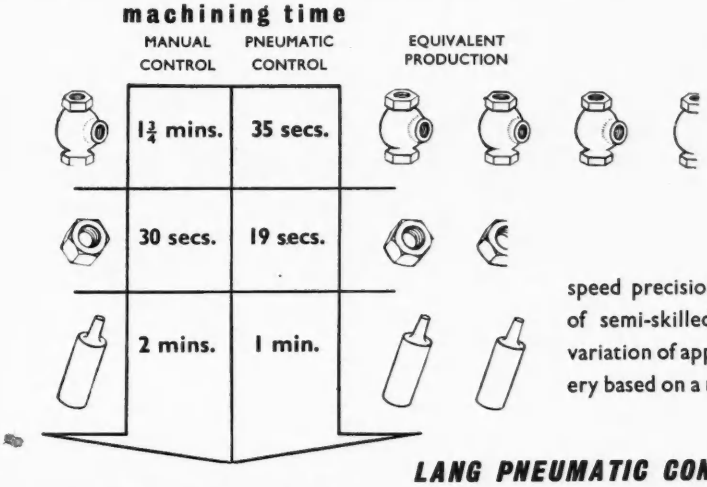

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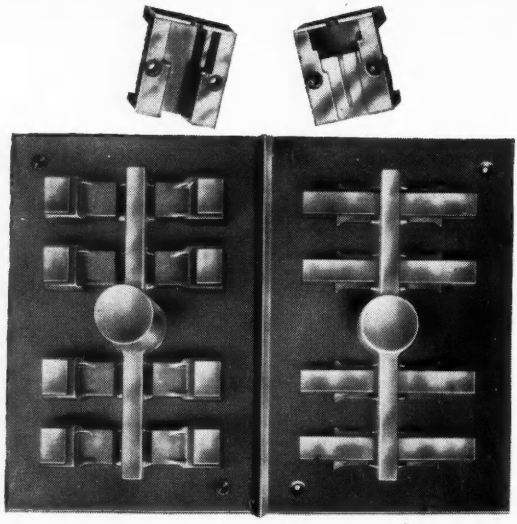

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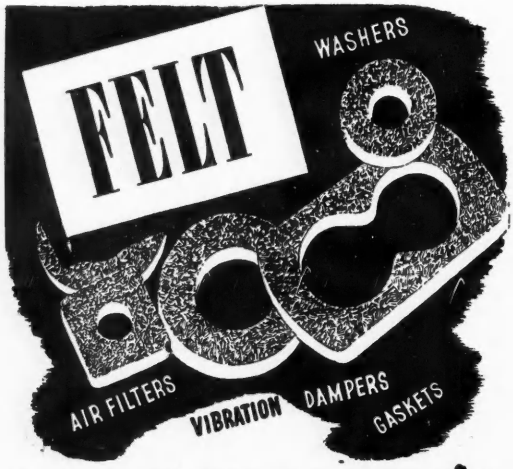

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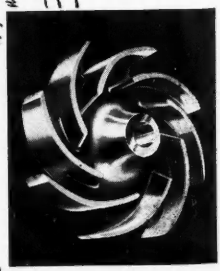

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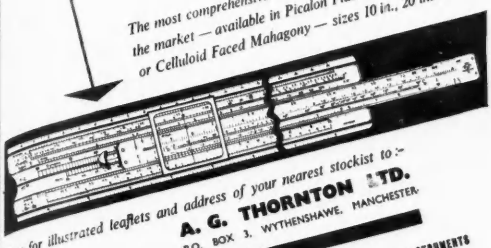

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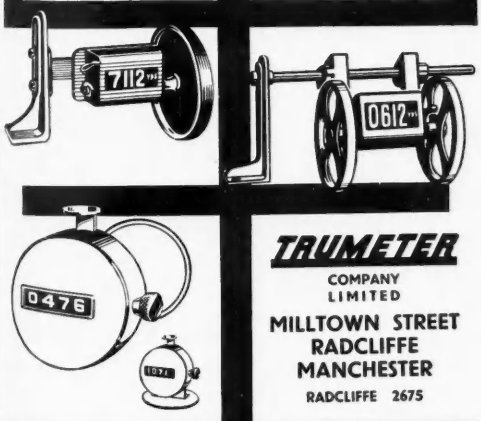

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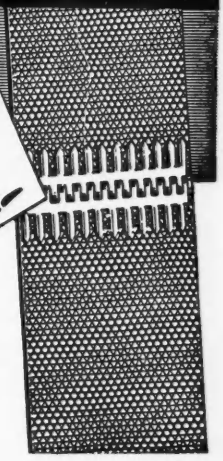

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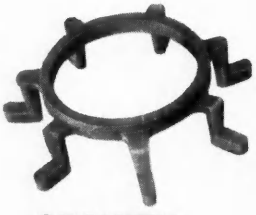

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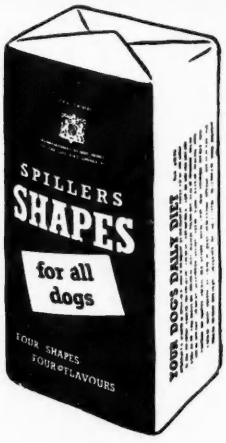

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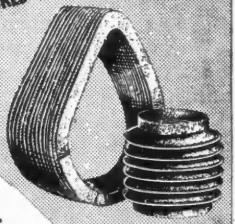

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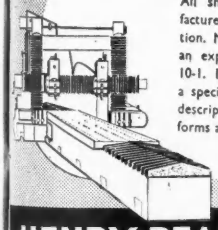

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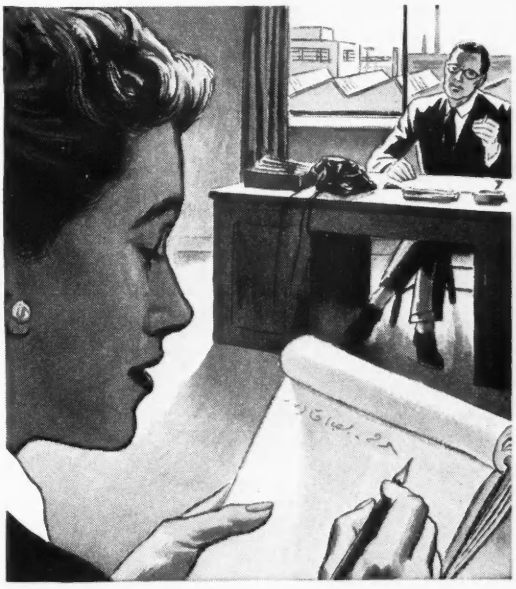

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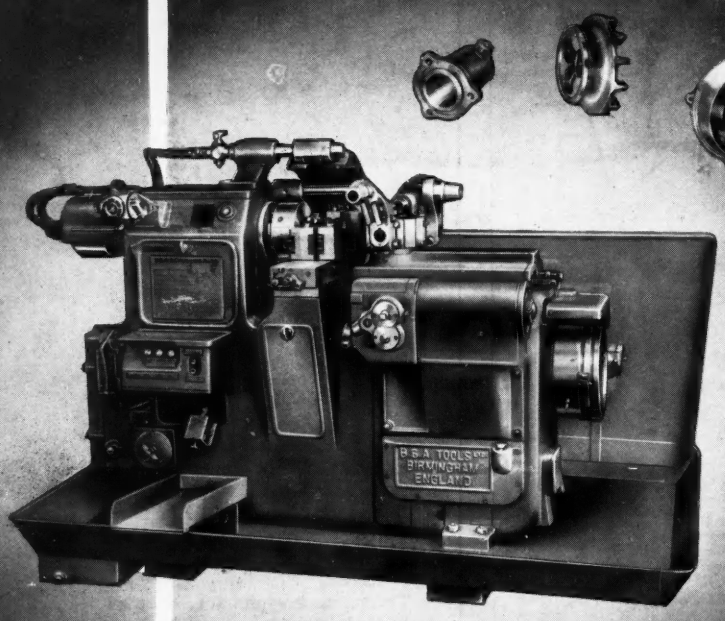

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